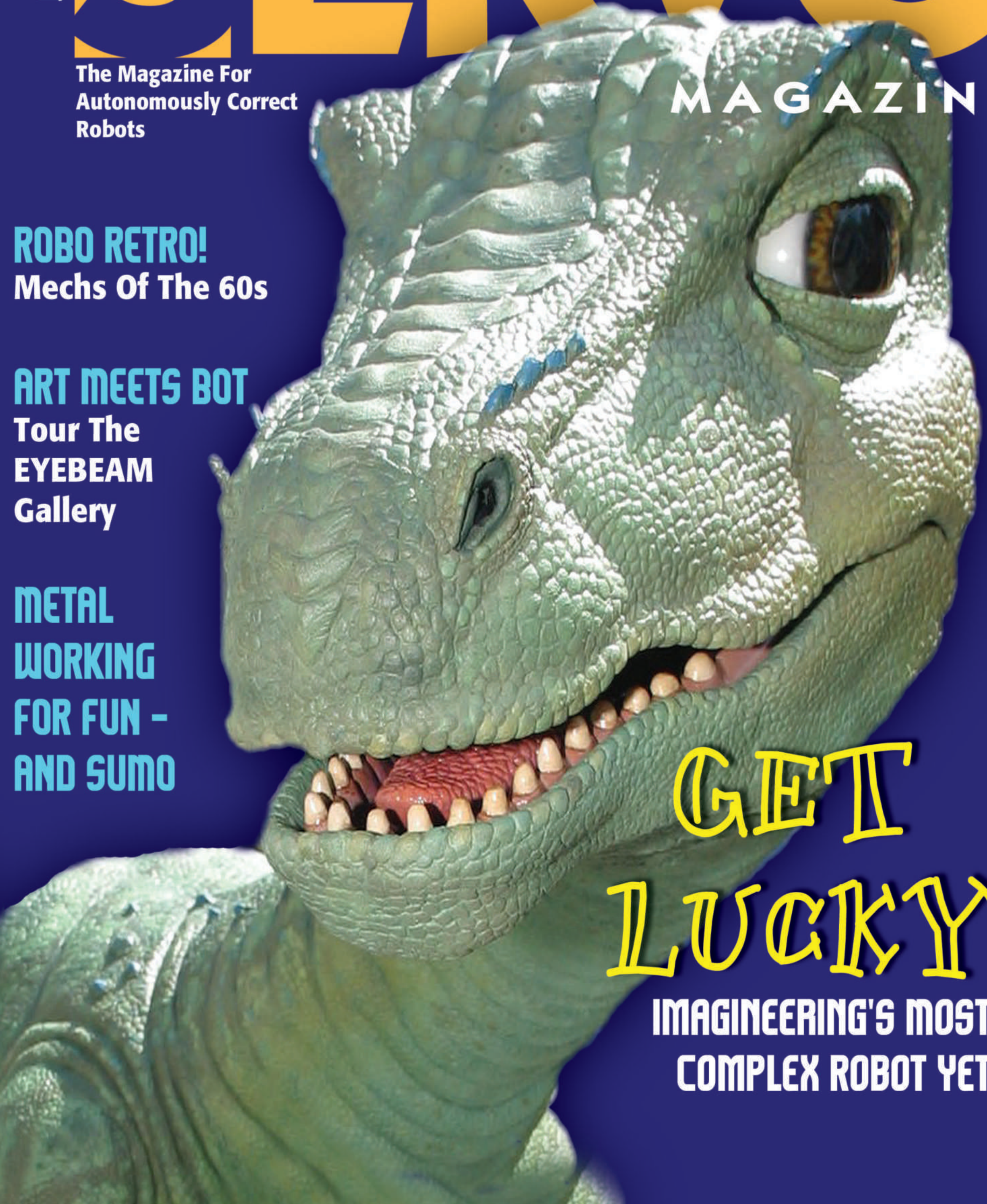
January 2004

SERVO MAGAZINE

The Magazine For Autonomously Correct Robots



ROBO RETRO!
Mechs Of The 60s

ART MEETS BOT
Tour The EYEBEAM Gallery

METAL WORKING FOR FUN – AND SUMO

GET LUCKY!

IMAGINEERING'S MOST COMPLEX ROBOT YET

features

01.2004

Lucky posing with Bonnie Hunt courtesy of DisneyForever.com

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Mind / Iron

by Dan Danknick

I'm a sucker for great quotes, especially the ones that resonate in my mind like a tuning fork — thoughts and associations line up by the purity of tone itself. So when I heard Pat Gordzelik say "Innovation in America is in its hobbies" on the Discovery Channel, it was as if a middle-A was just played on a Bosendorfer piano.

Pat is a team member on the Aurora (**www.aurorarocket.com**), a garage built, near-space rocket that exceeded mach two and 30,000 feet in a mid-2003 launch. That's pretty impressive for a team that mixed their own solid rocket fuel by hand. But is it unique? Surprisingly, I don't think so!

Here at *SERVO Magazine*, we've shied away from publishing the phrase "hobby robotics." That's because we feel robotics is on the cusp of rolling up the same curve that personal computers did in the 1970s. Our vision from the start was not simply to track this progress, but to get behind and push. And toward that end, every month we try to showcase the innovations of one, two, and three person teams — and how they are the engines of change.

From the high school students that built Bob V-2.1, and the brilliant minds of Bill Benson and Wayne Gramlich who are striving to deliver a distributed robotic control solution through their RoboBRiX, to the artists that converged at EYEBEAM to invite us to look anew at machine/human interaction, these hobbyists are helping to define the upward path.

If you think about it, personal computers had a first surge of interest when they were introduced, and building them was the main focus. But, that was later dwarfed by the demand that arose by their transition from goal, to tool.

Right now, I have no idea how fast the CPU in my desktop PC is running. And I don't care, because using it to produce this magazine is my goal. I need to send Email, reference facts on the Internet, crop images, etc. I could be running on silicon that natively executes LISP tokens instead of 32-bit Pentium instructions — it just doesn't matter!

Watch ... the same thing will happen with robotics in the next six years. The goals will be location monitoring, attention to repetitive tasks, delivery of materials over varying terrain, distributed data collection of natural phenomena, and more. Sensors, processing, and mechanical expression will become so well defined — and refined — that experimenters will pop up to the next meta-level — that of task description. This, is innovation.

I know this sounds neat and all, but here's the kicker — it's not too late to join in! There are small robotics clubs meeting all over the country, with a mix of newbies and CMU graduates that have the same goal in mind: build the next cool thing. They are incubators for creative thought, and motivators toward action.

So if you want in — jump in! The only mistake that will keep you from advancing is inaction. Heck, even Gordzelik wasn't afraid to mix up that first batch of rocket fuel.

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OUR PET ROBOTS
Guido
Mifune

BIO-FEEDBACK

Dear *SERVO*:

Is this a code or did your cat walk on the keyboard? Several lines in the December GeerHeads article don't make any sense at all.

Ringo
via Internet

A paragraph in last month's GeerHead column was inadvertently transmogrified to "Jabberwocky" by our desktop publishing software. And in the rush to the printer, we didn't catch it. The correct English text follows; thanks to all who called it to our attention. — Editor Dan

"In addition to the tiny controller, the right power, motion and sensor solutions had to be found. Casey Holmes' nano build is powered by one 3.7 VDC, 145 mAh rechargeable Kokam lithium polymer battery. For wheels, Casey used 0.4-inch diameter, 66 thousandths thick printed circuit board wheels, with O-ring tires. The gearboxes are super-hacked GWS Pico Ball Bearing servos."

Special effects mechanic and devoted *SERVO* reader Peter Abrahamson poses his latest issue against the Sydney Opera House while on location, filming in Australia.

If you've taken your copy of *SERVO* somewhere interesting, Email the picture to us and we just might publish it here! **editor@servomagazine.com**

Dear *SERVO*:

I'd like to tell you that I'm thrilled with *SERVO*, now it will help me out with robot building and extra credit time.

Thanks, and keep it up with the good work.

Richard Kosiek
Chicago, IL

Dear *SERVO*:

In regards to the article on Hexapod, in the Parts List, the values of R1, R2, and R5 were not identified. In Part 2 of the article, the schematic shows R1 as 4.7K, but R4 and R5 are still not identified. Is the assumption made that they are both 100 ohms to limit the current through the LEDs?

I found the article very thought-provoking.

Frank Inferrera
via Internet

R1 and R2 should be in the 220 to 270 ohm range, apologies for the omission. — Editor Dan

Dear *SERVO*:

I have read the December *SERVO* cover-to-cover. I have to say I think that you guys are slipping.

I can't believe that you didn't catch all the gibberish text in the Geerhead article (second column, top of page 29).

The splash pages for many articles are really bad. The art for my article doesn't even reference robotics! Duh. Is this a robot mag or what? It seems pretty clear that your art folks are trying too hard to fill pages with not much content. My article could really have used some more informative graphics rather than all that pointless art. I know, I know, that one got by you somehow. Must be all those burnout hours! I really think you should talk to the art dept. and get them to tone down the "arty" layout a bit though, they are just trying too hard to be "hip."

The Hexapod article could have used a separate parts list with source info for code, etc. And "Night of the living hexapod"!!! Yikes. What a dumb title.

The graphics in the "Consciousness" article were obviously copied from printed material and look very amateurish.

On the plus side, the content that was used was good. Particularly the Friction article (p. 60+). It was very well written and illustrated as were the iCybie article and the UHMW plastics fabrication article. All the other editorially generated sections were fine; New Products, Robytes, and Menagerie are well laid out and edited.

Hope you don't mind my brutally direct feedback. Overall, *SERVO* is great, I just had to offer my constructive criticism since I feel invested ...

Guy Marsden
author, via Internet

Continued on Page 35

Will Lucky The Dinosaur Transform Disneyland Into Jurassic Park?

by Edward B. Driscoll, Jr.

Meet Lucky. He's one year old, weighs 450 pounds, and is nine feet tall. He's also very green and scaly. But that's to be expected, because he's a dinosaur. And he could very well become the hit of Disneyland.

Lucky is not just any dinosaur. He's the latest in a long line of increasingly lifelike robotic figures at Disneyland and Disney World that Walt Disney dubbed "Audio Animatronics" back in the early 1950s.

Disney had purchased a mechanical bird while vacationing in Europe, which would be the initial inspiration for Audio-Animatronics. The earliest experiments, which predate the opening of Disneyland in 1955, utilized simple mechanical devices — cams and levers — to animate miniature scale model human figures such as Dancing Man, a nine inch tall tap-dancing vaudevillian, who was programmed to mimic the dance steps of the late Buddy Ebsen.


Photo courtesy of DisneyForever.com

Electronics, Hydraulics, and Pneumatics — Oh My!

Cams were tedious to cut, and the movement they could produce was limited to the diameter of the cam — clearly an inadequate approach to animate life-size figures with life-like movements and sounds. Eventually, the cam-and-lever principle was combined with an approach that included electronics, hydraulics, and pneumatics, to achieve more versatility than displayed by the moving "animals" of early Disneyland attractions such as the Enchanted Tiki Room, Nature's Wonderland, and Jungle Cruise. But the animation was still very limited.

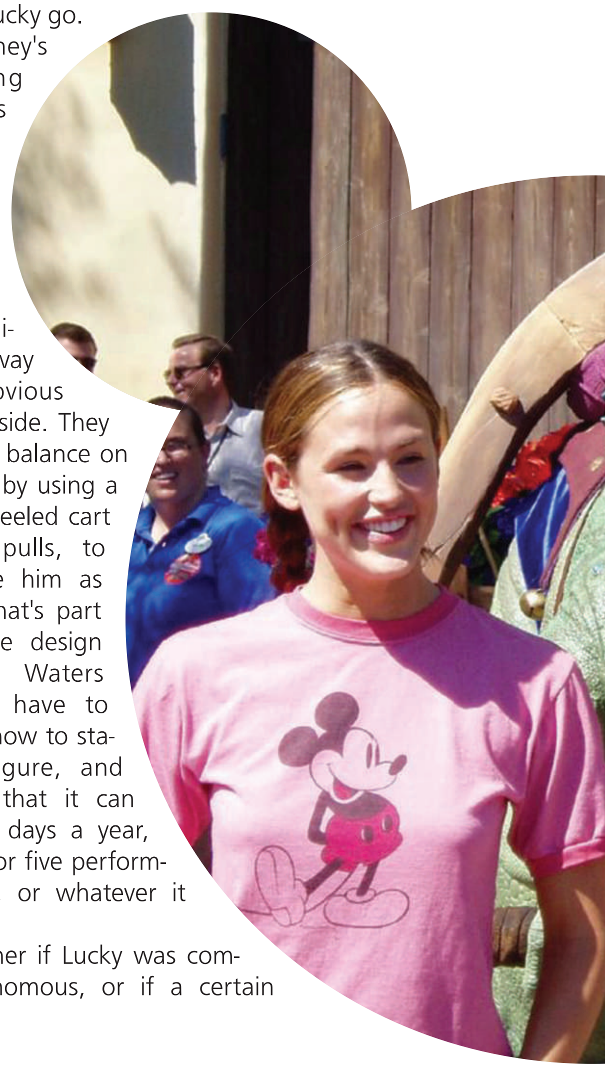
An early milestone was a recreation of President Lincoln, who appeared in both Disneyland and Disney World, and could sit down, stand up, and talk. Major breakthroughs in mating early computer programming with animatronics during the 1970s and '80s allowed for even greater subtlety of movement and expression. A key stepping-stone on the way to Lucky was a recreation of Ben Franklin in The American Adventure at Disney World's Epcot Center. Franklin's head tilts and nods, his body twists, individual fingers of his hand move, his torso moves forward and to the side, and his mouth "pinches" right and left. All in all, some 40 separate movements were required. "To accomplish this, we had to push our abilities to the limit," the late Wathel Rogers, who pioneered Audio-Animatronics, observed during the show's premiere in October 1982. "When the process was finished, we had the most complex Audio-Animatronics figure ever built."

Free Range Dinosaurs

Of course, Lucky's complexity leaves the recreation of Mr. Franklin in the dust. Perhaps the most important difference is that he moves independently. Marilyn Waters, the director of communications for Disney's Imagineering division, says that the one thing the animatronic figures have never been able to do is to walk about freely, "and that's because the technology was hydraulic, so the size of the equipment, and the fact that there were pumps and hydraulics involved, meant that it had to be tethered to the ground."

In contrast, the significant breakthrough with Lucky "is that we now have a figure that can walk and move independently: because of electric actuators, batteries, and computerization, which have helped miniaturize a lot of the equipment that's necessary to run these. And so, that means that guests can get close to these figures, can interact in a much more personal way with them than before." But Lucky does more than just walk around unaided. He responds to both visual and verbal stimuli.

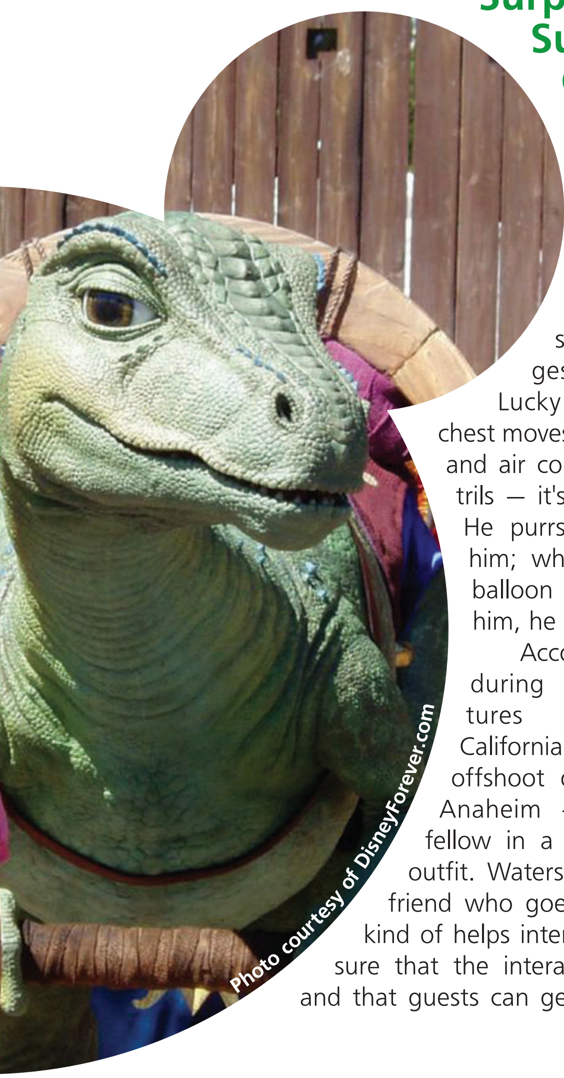
Waters is understandably cautious about revealing much of the technology that makes Lucky go. But Disney's Imagineering team was able to solve one common robotic problem — balancing a life-like two legged animal, in a way that is obvious from the outside. They helped Lucky balance on his hind legs by using a large two-wheeled cart that Lucky pulls, to help stabilize him as he walks. "That's part of the whole design process," Waters notes. "You have to think about how to stabilize the figure, and make it so that it can operate 365 days a year, and do four or five performances a day, or whatever it ultimately is."



I asked her if Lucky was completely autonomous, or if a certain

amount of remote control was involved, and she said, "Well, let me answer that in a couple of ways. There's quite a bit of animation software that is used. Some of the movements are pre-programmed — but not all of them. And there is a human element that is involved that allows for that personal interaction, because there's nothing that can replace the human touch when it comes to some of the subtleties of human interaction. So there is a person involved in how Lucky interacts with people — but most people can't figure it out!" And Disney's obviously not going to help them figure it out, either.

Surprisingly Subtle Gestures



Subtlety is rarely a word associated with a 12-foot long dinosaur. But Lucky is capable of some surprisingly subtle gestures. "When Lucky breathes, his chest moves, his nostrils flair, and air comes out his nostrils — it's very believable. He purrs when you pet him; when he loses the balloon he carries with him, he cries."

Accompanying Lucky during his recent ventures into Disney's California Adventure — an offshoot of Disneyland in Anaheim — has been a fellow in a medieval wizard outfit. Waters says, "That's his friend who goes with him, and kind of helps interpret, and makes sure that the interaction goes well, and that guests can get close, and can pet him and touch him." He also helps Lucky sign autographs. "We give Lucky a Magic Marker, which he holds in his mouth, and his autograph is a four-leaf clover."

According to Waters, Lucky's wizard-like sidekick has little control over Lucky's actions, but there is someone monitoring the big green fellow, in case something goes wrong. The wizard also encourages visitors to approach and interact with Lucky — there's nothing worse than a lonely audio animatron.

What's Next for Lucky?

What's next for Lucky? Waters says, "We've done our testing and we've had him out at the park for a couple of months. Now he is back at R&D, and they're doing what we call the 'tech-transfer process.' We've proven that this will work with good guest feedback, so now we have to take a look at how can we recreate this as a permanent figure that could operate every day for X-amount of time (with appropriate maintenance_ and that we can offer repeatable terrific experiences."

Does this mean that there will be an animatronic dinosaur at every Disney park? Don't expect Disneyland to turn into Jurassic Park just yet, Waters says. "I can't tell you in five years what you're going to see as a result of this. Except that you'll see something — we could have a live entertainment show where we have dancers and singers and actors, and there's an Animatronics figure in there as part of the program. There are a lot of opportunities there. Or, it could mean that one day, you could see one of the presidents in the Hall of Presidents get up and walk off the stage."

"We're always trying to help our guests have experiences where they are immersed in the story. And this is pretty good — to be able to actually come up and interact with an Animatronics figure that knows you're there, knows when you've raised your hand, knows what you're wearing, and can respond to you in a very personal way." SV

Exclusive Interview! The Early Days of Disney's Animatronics

Steve "Mouse" Silverstein is the principal animation programming systems developer for Disney's Imagineering division. Does he have much personal experience with animatronics? "About 20 years worth!", he immediately quips.

He's worked firsthand with men who Walt Disney hand picked to develop Audio Animatronics (AA) back in the early 1950s; he's seen animatronics evolve from a system of cams and rods, to the sophisticated computerized technology that powers Lucky the dinosaur. And he's participated in a whole lot of trial, error, and experimentation along the way.

Audio Animatronics' Grandfather

The earliest methods for "teaching" animatronics figures to move involved inputting the movements of a live man in a harness that recorded his movements to an early audio tape-based data system called 'tones on tape.' The first man in that harness was Wathel Rogers (1919-2000), whom Silverstein calls "the grandfather of AA."

Silverstein says that Rogers "was kind of a jack-of-all-trades; not only did he have a formal artist's background, but he also tinkered a lot with mechanical things, and just really loved animation — both film and three dimensional animation. So he took it upon himself in some ways to help develop the first programming systems. He did a lot of the animations for the 1964 World's Fair. He was in the programming harness making the motions for Abraham Lincoln, for example. He had this thing that took around 20 to 30 minutes to set up, and he would get all stiff and worn out, and was absolutely exhausted by the end of these programming sessions."

Starting Small

At first glance, it would seem that the large size of characters such as the AA President Lincoln would be easier to animate than the smaller figures, if only because there was more room to hide the mechanisms. But in reality, animatronics began small, as Walt Disney instructed his employees to figure out what made the small mechanical toy bird he received as a gift, tick. From there, animatronics worked its way up to full-size humans, on the way to medium-sized dinosaurs.

Silverstein says that Disney had the machinists at his studios "basically take the thing apart to make it work." From that, the miniature mechanics and every other element of the animatronics, started on a small scale, beginning with "Project Little Man," a miniature dancing man whose movements mimicked those of hoofer Buddy Ebsen. "Wathel worked with Roger Broggie, another pioneer and mechanical genius who worked on a lot of the early animation testing.

So they really started off small, trying to get a grip on how to get the controls to work correctly, how to program it, and how to animate it."

Animatronics Goes Digital for Disney World

Computers would begin to play a role in the programming of the animatronics figures, but not until the late 1960s, when new technology was developed in anticipation of the opening of Walt Disney World in Florida. Prior to that, Silverstein says, "all of the audio animatronics figures were controlled by cams or by tones on tape."

"The stories I heard from Wathel about why the investment was made to go to computers and to try to make the system all digital, was because it was just such an enormous task, trying to program the figures the existing ways, doing it with tones or with cams."

"They realized at the time that it would be pretty much impossible to open up Disney World, unless they were able to take advantage of the new computer technology of the time."

Taking advantage of new, emerging technologies would prove to be a strong suit of Imagineering to this day. Just ask Lucky! SV

Steve "Mouse" Silverstein

ASK MR. ROBOTO

by Pete Miles

Tap into the sum of *all human knowledge* and get your questions answered here! From software algorithms to material selection, Mr. Roboto strives to meet you where you are. And what more would you expect from a complex service droid?

roboto@servomagazine.com
Our resident expert on all things robotic is merely an Email away.

Q. To start off I must say Wow! What a great magazine, just the thing to inspire the wild minds of the future.

I would like to know more about the different types and name brands of servos. I have seen most airplane R/C shops have servos that rotate 60 degrees.

Are there ones with 180 and 360 degree ranges? I have been experimenting with a new aircraft design and I need to know what is currently available. Keep up the great work.

— Wayne Bartrug
via Internet

A. Thanks. We are working hard at putting together a quality magazine that you will want to keep for years as a personal reference to all your robotic related projects.

Just about all of the servos that I am aware of will rotate somewhere from 170 to 200 degrees, and some sail winch servos can rotate about 300 degrees.

What may be confusing here is that *all* of the radio control (R/C) servo manufacturers specify the transit speed of the servos as a time per 60 degrees of motion, at either 4.8 or 6.0 volts. This can give the impression that they can only rotate 60 degrees, but just about all of them can actually rotate 180.

There are about a dozen different companies that manufacture R/C servos, and each of these manufacturers produce a few dozen different models to choose from. Table 1 shows a list of some of the most popular servo manufacturers. The system 2000 and 3000 servos from Tower Hobbies are actually Futaba and Hitec servos under the Tower Hobbies brand name.

It is hard to describe all the different types of servos that are available since there are hundreds of them to choose from.

Size is usually one of the deciding factors. There are servos as small as 0.9 x 0.4 x 0.8 inches that weigh as little as 0.3 ounces, and there are servos as large as 2.4 x 1.2 x 2.0 inches that weigh about 4.4 ounces.

Torque is another factor. Different servos have different torque ratings. The torque rating of a servo is its stall or holding torque, and is usually given in terms of oz-in or kg-cm (1 kg-cm = 14.15 oz-in).

The torque ratings are specified at either 4.8 or 6.0 volts, and sometimes both. The higher the voltage, the greater the holding strength the servo has. Some of the high powered servos have torque ratings up to 290 oz-in! Also, higher voltages mean faster transit speeds. Some of the high speed servos have transit speeds as small as 0.06 seconds/60 degrees.

Most servos use nylon gears, but the high strength servos use metal gears. These servos usually have an MG designation in the model number. Metal gears are recommended for either high torque applications or when high shocks to the gear train are anticipated.

The low cost (budget) servos don't use ball bearings on the output shaft. The long life and precision servos that have the ball bearings usually have a BB designation in their model number. Many of the higher torque and faster servos use a coreless motor instead of the traditional iron core motors we are familiar with. The coreless motors are for high performance applications and are significantly more expensive than the standard servos.

The newest type of servos that are available are the digital servos. Though all servos receive a digital signal from the R/C receiver, the internal electronics actually use analog signals to control the motor position. The new digital servos use higher speed digital internal signals to control motor speed and position.

The new electronics enable these servos to move smoother, faster, and with higher torque ratings. The digital servos can be used with standard R/C equipment, but to take advantage of their programmable features, such as adjusting the center position or velocity, you will need a special programmer for the servos.

The main drawback for the digital servos is that they are significantly more expensive than all of the other similar sized servos.

As time goes on, you will get to read about all the different things you can do with these incredible little machines (R/C servo motors) in future issues of *SERVO Magazine*. In the mean time, selecting the right servo for your application really comes down to determining which ones

meet your torque, speed, size, weight, and cost limitations.

Visiting the servo manufacturers websites will give you a lot of information about all the different types of servos that are available.

Q. Dear Mr. Roboto, I've started noticing these nickel-sized patches on the rear bumpers of modern cars. I think they're ultrasonic distance measurement transducers for back-up tone generation. Since they're mass-produced, could those be (cheaply) used in robotics? If so, how would I interface one to my microcontroller?

— Anonymous via the Internet

A. Just because something is mass-produced for the automotive industry, doesn't mean they are cheap to the average consumer.

Table 1.
R/C servo manufacturers and their websites.
Futaba **www.futaba.com**
Hitec **www.hitecrcd.com**
Airtronics **www.airtronics.net**
Cirrus **http://cirrus.globalhobby.com**
JR **www.jrradios.com**
FMA Direct **www.fmadirect.com**
System 2000/3000 **www.towerhobies.com**
GWS **www.gws.com.tw**
Multiplex **http://multiplexusa.com**
Ko Propo **www.kopropo.co.jp**
Sanwa **www.sanwa-denshi.co.jp**

For the most part, these sensors are options for the high end auto market, thus they sell for a premium right now. Ford has a relatively low cost system called "Reverse Sensing System" that retails for about $250.00.

The prices for these systems from other automotive companies go up from there.

Automotive ultrasonic systems may not be the best object sensor for a robotics project (at least with the current system).

The reason for this is that they are generally designed to only emit a tone or light three different LEDs that represent some distance from one foot to four feet from the rear bumper.

These systems are designed to alert the driver, in a very simple way, that something is behind the bumper of the car. They are not designed to provide analytical data that could take time to interpret.

When considering low cost options for ultrasonic systems for robotic systems, take a look at the Sonic Range Finders from Devantech (**www.robot-electronics.co.uk**) or the SensComp, Inc./Polaroid (**www.senscomp.com**) ultrasonic sensors.

These sensors have become the ultrasonic sensors of choice for both the amateur and professional robotics communities. Devantech sells the SRF04 (one inch to 10 foot range) and the SRF08 (one inch to 20 foot range) sensors.

The SensComp 6500 ranging module has a longer six inch to 35 foot range over the Devantech sensors.

All three of these sensors can be obtained at Acroname (**www.acroname.com**) from $34.00 to $49.00 each. These sensors output a digital pulse that represents the time of flight of the ultrasonic ping from the sensor to the object back to the sensor. This signal is easily connected

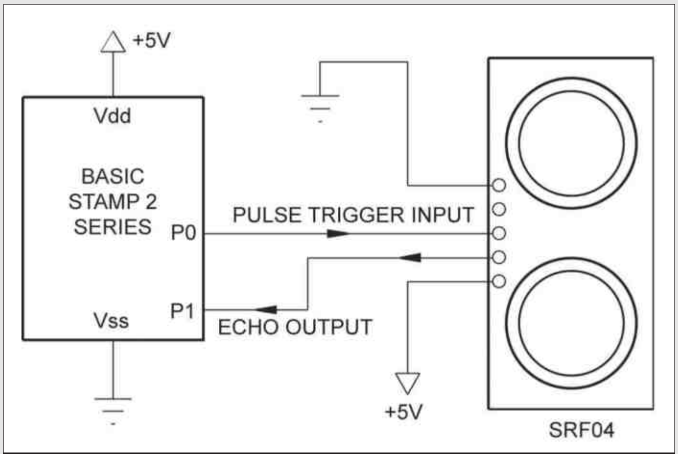


Figure 1. Connecting a Devantech SRF04 to a BASIC Stamp.

```
'{$STAMP BS2p}
' Deventech SRF04 test program for the
' Basic Stamp. 'This program will output a
' 10 us (min) pulse to the sensor, and then
' measure the return time, in pulsin periods.
' The time is the round trip time, so the
' actual distance is half the round trip
' time. The conversion factor is used to
' convert the number of measured pulsin
' periods into distance. The speed of sound
' is ~13560 in/sec.
' Below lists the conversion factors for
' different types of Basic Stamps.

' Pulse Trigger line on I/O Pin 0
Init      CON      0
' Echo Signal line on I/O Pin 1
Echo      CON      1
' Number of time periods for round trip
Trip      VAR      Word
' Distance between the object and SRF04
Dist      VAR      Word
' Use 74 for BS2, BS2e; 184 for BS2sx and
' 197 for BS2p-24 and BS2p-40
Convfac   CON      197

Main:

' Initialization pulse of 10 us minimum
  PULSOUT Init, 15

' Measure number of periods for round trip
  PULSIN Echo, 1, Trip

' Convert round trip periods into distance
  Dist = Trip/Convfac

' 10 ms minimum delay between measurements
  PAUSE 10

' Display the distance
  DEBUG DEC ? Dist
' Pause for 1/4 second to see the distance,
' remove when not using the Debug
  PAUSE 250

GOTO Main       ' Take another measurement
```

to a microcontroller. Figure 1 shows a schematic for interfacing a Devantech SRF04 to a BASIC Stamp from Parallax (**www.parallax.com**). The source code example is a simple program for reading in the results from the ultrasonic sensor and displaying the results to the debug screen of the program.

Q. Dear Mr. Roboto, I received my first *SERVO Magazine* and it was very enjoyable! Good start, keep up the good work.

I've been using BASIC Stamps to control robots and other motor circuits, but now I would like to get into motion control for machinery in order to make some of my own robot parts and injection molds with the use of a CNC mill.

I would like to see an article including schematics for a (low budget) three axis controller of either steppers or servos for a small milling machine. I've done this with kits but would like to scratch build next time. Thanks.

— Matt Slauson via the Internet

A. You are subscribing to the right magazine for all of this information. Unfortunately, a single article cannot provide enough to describe how to build everything that is needed to build your own three axis CNC (Computer Numerical Controlled) mill, but a series of articles will be needed.

In future additions of *SERVO Magazine*, we hope to print many articles on how to do this, so stay tuned for the fun and exciting world of building your own CNC machines.

Q. Hello. Is there any commercial robot available that can type on computer keyboards and/or move a computer mouse? Thanks.

— Kaushik Narayanan via the Internet

A. Well, this all depends on what you mean by typing on a keyboard. If you are interested in robotic hands like human hands, then you are going to have to wait until technology improves.

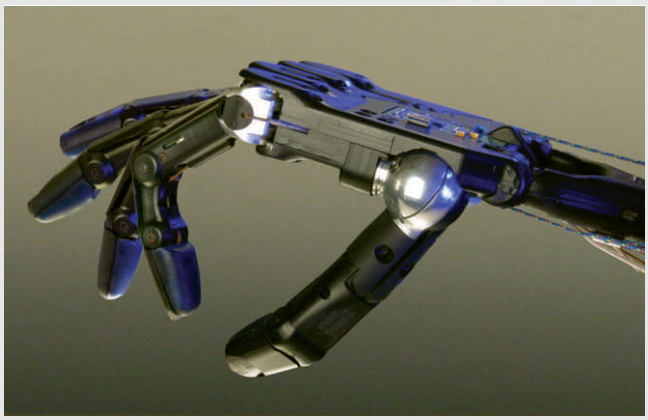
The human hand is extremely complicated, and for the most part, artificial hand research is still in the government and university research labs. The closest option that you have right now is the Shadow Dextrous Hand that has been developed at Shadow Robot Company (**www.shadow.org.uk**). They developed a rather sophisticated robotic hand using their air muscle technology.

Most likely you may have to use some sort of a pick-and-place robot such as an Adept robot (**www.adept.com**).

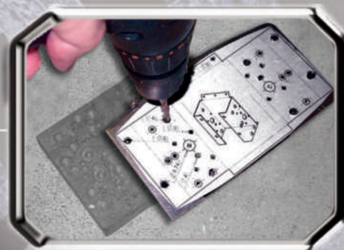
Instead of fingers, the robot would have an end-effector that will plunge up and down to press the keys, and have a gripper for holding onto the computer mouse, and use the plunger to press the buttons on the mouse.

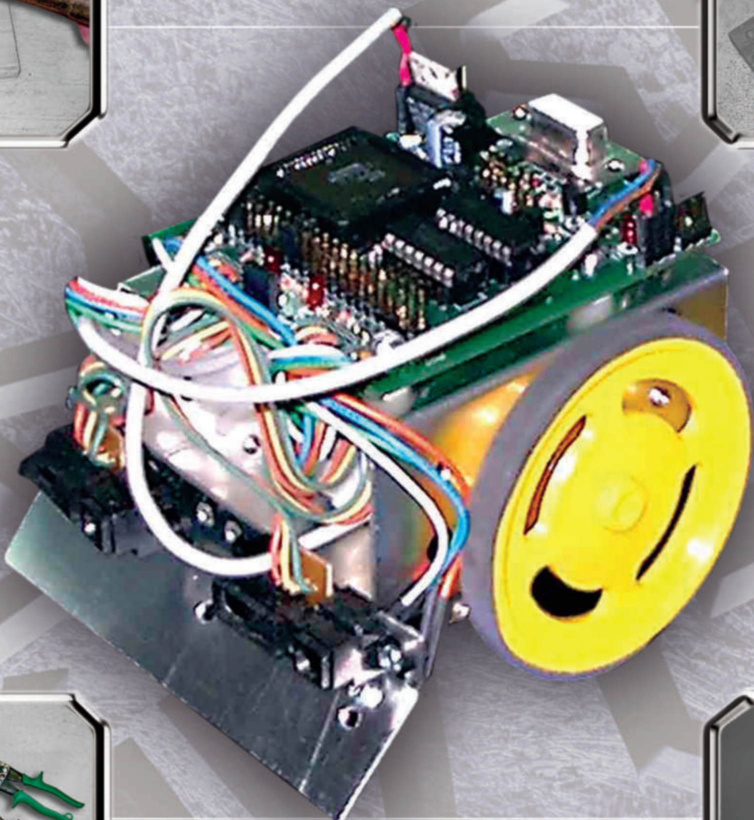
If they can load components on a circuit board, they should be accurate enough to type on a keyboard. **SV**

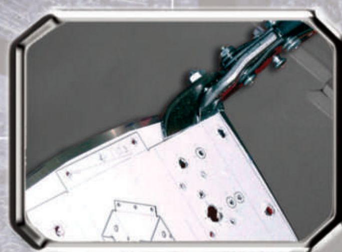
Photo courtesy of The Shadow Robot Company



CUTTING EDGE ROBOTICS:







A MULTI FUNCTION ROBOT

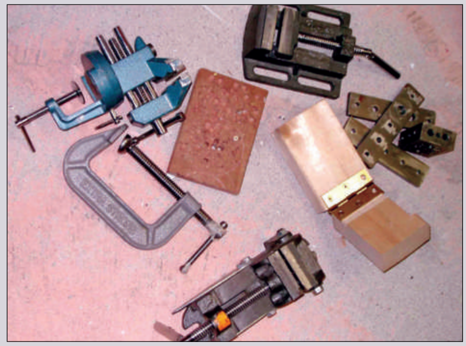
PART 1

by John Myszkowski

FIGURE 1. Band-Aids. Smart idea to have a good supply on hand.

FIGURE 2. Various sheet metal robotics projects.

FIGURE 3. Jig material. A variety of wood and metal pieces.



Over the years, people have employed various methods of fabricating robots and robotic attachments. I am going to present one such method. I call it the "Cutting Edge Robotics" method.

Safety First

I will begin with the issue of safety. I can't stress this enough. As many people have unwittingly found out, with the "Cutting Edge" method you may need a box of "band-aids" (Figure 1). It may sound like a joke, but "cutting edge" means exactly that, the edge that cuts. Sheet metal has an extremely sharp edge that will cut if not handled with care.

The method is quite safe, but it is advisable to use common sense and observe all safety precautions. Hand tools are inherently safe, but the materials that you handle are sharp — very sharp. If you are prone to paper cuts, then extra care is suggested. Yet, with safe handling of tools and materials, you should have a fun time constructing your projects.

One Robot, Many Functions

Metal is a flexible and lasting material for making almost anything, if you have the right design and method. I will not show you how to design, but I will show you the basic sheet metal fabrication method.

Using this method you will construct a flexible robotics platform (Figure 2). The robot will be able to compete in a mini sumo ring. Follow lines. And be converted into a crawling robot. And eventually, change into the ARM (Advanced Robotic Manipulator).

Many popular kits are simply pieces of hardware that you assemble. We are going to make the components by ourselves rather than buy the ready-made kit. This will give you experience, confidence, and extra coffee money in your pocket.

In a Nut Shell

Working with metals can be a pleasurable experience. It also means you need to make jigs and fixtures (Figure 3). These do not have to be made solely from metal, but can be made from other materials as well.

I prefer to use jigs and fixtures made from wood and preformed metal extrusion. I use whatever is close at hand at the time. Wood is favored simply because it is plentiful and can be cut and shaped with impunity.

In this situation, we need to cut and bend sheet metal. We will need jigs and fixtures for holding and neatly bending it. At the end of the process, all "cutting edges" have to be made safe to handle.

FIGURE 4. Sheet metal working tools. Wide nose Vise Grips, left hand snips, center punch, nibbler, right hand snips.

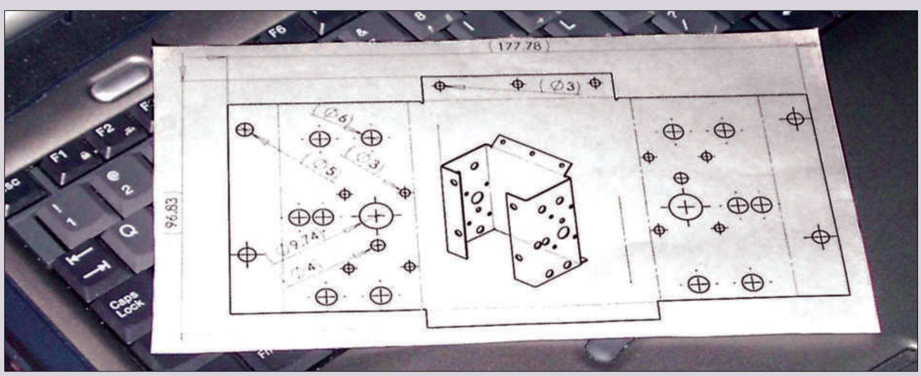


FIGURE 5. Paper layout hot off the press. Printed 1:1, the layout is ready to use.

The ARM can be made from sheet metal using only small hand tools (Figure 4). Power tools — such as a band saw — are helpful but not necessary. See Table 1 for necessary tools and some optional ones.

The process is simple: mark, drill, cut, bend and finish. In that order. In reality, it is a little bit more complex.

It Starts on Paper

First, we need the most vital component: the design layout sheet (Figure 5). The layout sheet is a drawing of the sheet metal part, as it looks before it gets bent. I like to use a CAD (computer aided design) program to design my parts. A neatly hand drawn layout will suffice in many situations.

Make sure to place all necessary dimensions and written directions within the cut marks. This will ensure that the markings will stay on your work piece after it is cut and trimmed.

Print the layout at 100% or 1:1. Check your dimensions after printing.

Once your design is finished and printed, all you need to do is cut out the parts.

In this article, we will build a robot base that serves as a platform for other Cutting Edge Robotics projects. We will start with the layout of the mini sumo chassis (Figure 6).

First, you need to cut out, photocopy or scan, and print the chassis layout from this article. You can also access the PDF file from the *SERVO* website at **www.servomagazine.com** and print it out for best results (this will also save the magazine article for others to read).

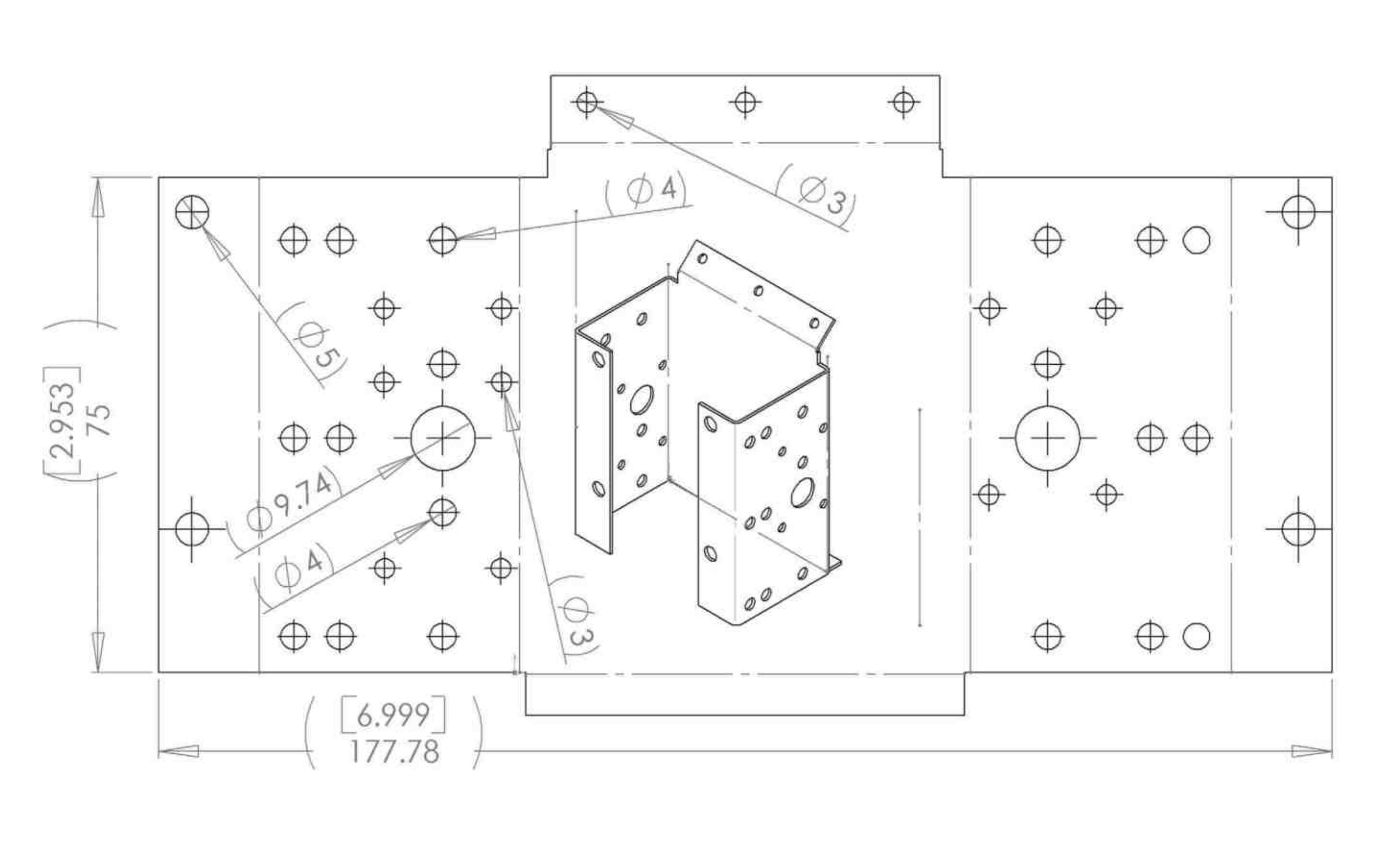
Now it Gets Sticky

The paper layout gets glued onto the surface of your sheet metal.

I use a cheap, dollar store variety of glue stick to do the glueing (Figure 7). First, coat the back of the paper evenly and thoroughly with the glue. Then, coat the metal surface where you want the paper to stick. It is best if you cut the paper and the sheet metal approximately the same size.

Now, place the glue-coated paper on the glue-coated sheet metal. Burnish the paper well into place, making sure there are no creases. Any creases will change the dimensions of your layout and consequently, the finished part. If two or more parts are to be able to mate afterwards, then you should avoid any creases. Burnishing simply

FIGURE 6. Chassis layout 1:1. All dimensions are metric unless otherwise specified.



means rubbing the paper down with the flat end of a stick or the back of your nails (Figure 8).

Make sure all of the layout lines actually fit on the sheet metal. Simply put, if the layout doesn't fit on the material, then the material is too small to become your part. It happens.

Sometimes, you pre-cut your material too small. If that's the case, then just get another piece. You can reuse the smaller piece for another project, later.

The glue is usually just strong enough to hold the paper. It will hold long enough for the metal shaping operations.

Holey Quest

In general, sheet metal work is not rocket science. The dimensions can be off when cutting the sheet metal, so any mistakes can be easily fixed by filing or bending, etc.

The holes, on the other hand, usually have a function. Whether it is for mounting components or joining other sheet metal parts together, it will be necessary to align two parts accurately. Because of this, it is my preference to drill the holes first.

Remember, safety first — You will need safety goggles.

To the Point

To make sure the holes are in the right place, I use a center punch to make an indentation in the metal (Figure 9). This will ensure that when I drill the hole, it will start at the indentation (Figure 10).

The holes are to be used for mounting, so it is important to make sure they're drilled in the center of the mark. If the hole is off center, then it is very likely that it will not align with its intended target.

On the other hand, if the holes are for decoration or ventilation, then it is only their cosmetic properties that you need to worry about.

A center punch can be anything

FIGURE 7. Sheet metal and paper layout ready for glueing.

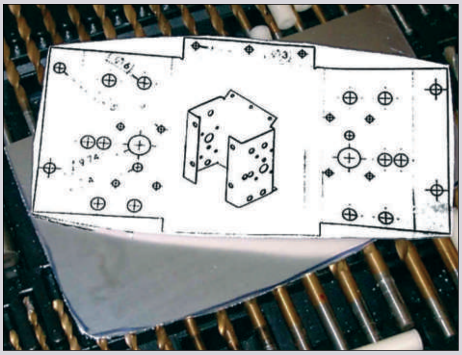


FIGURE 8. Burnishing the sticky paper on the metal with the back of my fingers.

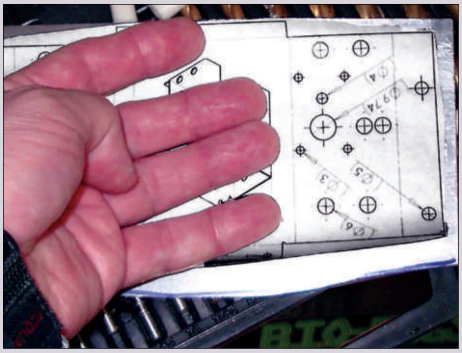
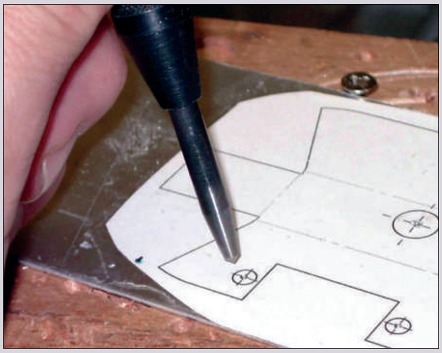


FIGURE 9. An automatic center punch makes the much job easier.



Parts List

1 — 4" by 9" piece of aluminum sheet about 3/64" thick (local hardware or automotive store)
2 — GM2 gear motors (Solarbotics)
2 — Wheels (Solarbotics)
1 — 4AA battery holder (RadioShack)
2 — Velcro™ dots for mounting the 4AA battery holder
1 — 9V battery clip (RadioShack)
1 — Sumo11 controller, kit or pre-assembled *
2 — Sharp GP2D12 Distance Measuring Sensor *
2 — Fairchild QRB1134 IR Photoreflector *
4 — 8-32, 1/2", screws, nuts, lock washers for mounting the controller
4 — 4-40, 1" screws, nuts, lock washers for mounting the GM2 motors
2 — 4-40, 1/4", screws, nuts, lock washers for mounting the scoop
4 — 4-40, 1/2", screws, nuts, lock washers for mounting the sensors
* These parts are available from Tim Rohaly (see Resources)

Tools Needed:
Drill — portable or stationary
Tin Snips — left and right or straight
Files — for filing off sharp metal edges
De-burring Tool — smoothing sharp metal edges
Vise Grips — regular size and wide nose for bending sheet metal
Scrap wood and metal chunks for making bending jigs
Drill Bits — check layout for sizes
Vise — the bigger, the better
Flat piece of wood — for drilling on

from a large nail to a proper, spring loaded, automatic center punch. Whatever you decide to use, it is important that the business end (or the point), is sharp. A dull center punch is much less accurate than a sharp one. A newly purchased punch is most likely ready without sharpening.

After marking all the hole centers, you can start drilling holes.

Safety Tip

Again, I have to remind you of safety. When drilling holes in sheet metal, it is possible for the drill bit to grab your work and spin it around at high speeds. That, in effect, makes it a spinning weapon of carnage.

Okay, I may be exaggerating a little, but your fingers could get caught by the spinning piece of metal and get badly sliced up or even cut off (in the worst case). You can greatly reduce that possibility from occurring by observing some simple precautions.

First, you need to make sure your work piece cannot rotate, even if it gets caught by the biggest drill bit. This can be done simply by using a vise or placing something in the way to prevent the spin.

What I do, is use a small wooden board to support the piece of sheet metal and a small wood screw inserted into one side of it (Figure 11). The screw acts like a door stop for the work piece. The wood is a nice drilling surface as well as a good backing material for drilling, which gives a better finish.

Safety and functionality together, that's pretty good.

Drill Floor

The best drill bits for sheet metal are the ones that have a sharp, brad point in the center and sharp, pointy "wings" (Figure 12). When you look at the side of the drill bit, the end looks like the letter "M," with the center point longer than the side "wings."

These pointy drill bits have much less tendency to grab your work and leave a nice smooth edge. Regular drill bits tend to wander around the center mark before biting into the surface. They also tend to pull the material into the bit.

If you do not own sheet metal drill bits, then this is a good time to get some. The cost of a good set of drill bits, that are most suitable for sheet metal is not significantly higher than regular bits.

Figure 12 compares some of the different drill bits available at your local hardware store. Use whatever you have that gives you satisfactory results, just

FIGURE 10. Brad point of the drill bit will fit right into the center punch mark.

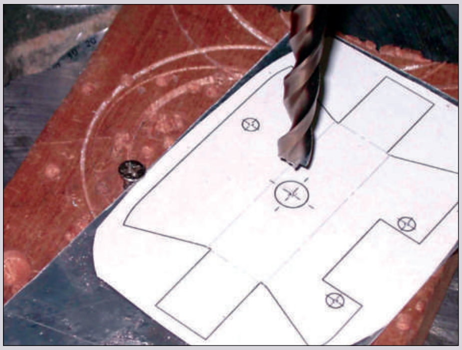


FIGURE 11. Drilling the holes using a hand drill. Notice the screw used to limit work piece rotation while drilling.

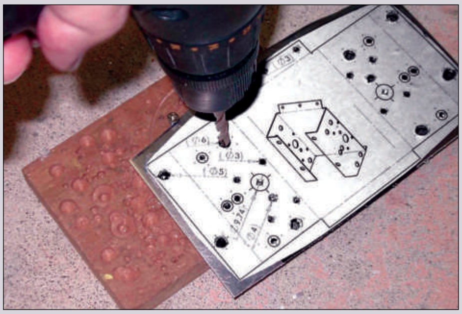


FIGURE 12. Various drill bits found in a regular hardware store.

make sure it is sharp.

When properly maintained, drill bits will last for a very long time.

Cut!

It's now time to cut the parts out. I use simple "tin snips" (Figure 4). You can find them in any hardware store in the tool section. I even found some in a dollar store (can't beat that!) They were actually the same as the ones I found in the large "home" type of hardware store. At a dollar store price, you don't need to worry about sharpening them (but, I sharpen mine occasionally, anyway).

You can also use a band saw for this, but we will concentrate on hand tools as much as possible.

When you cut, you should remember that it is usually better to cut less than more. Of course, it is best to cut just right. Cut in the center of the solid black line (Figure 13). The broken or "dotted" lines are bending guides.

Sheet metal is pretty forgiving (if you ignore all the nicks and cuts on your hands, that is). If your cut is not even, you can touch it up later with a file. If too small, you can re-cut. If too large, it probably won't matter ... maybe.

Resources

Solarbotics
www.solarbotics.com
Gear motors and matching wheels

Tim Rohaly *www.junun.org/MarkIII/Store.jsp*
Sumo11 controller, R/C servos

Servo City
www.servocity.com
R/C servos

RadioShack
www.radioshack.com
Battery holders, misc. hardware

Nova Robotics
www.novarobotics.com
Pre-made chassis

Brake Time

After drilling and cutting out the part, you need to bend it. Bending is what makes or "brakes" your project. For quality bends, we need a tool called a "brake," or metal brake, for short (but don't confuse it with a coffee break).

A brake is simply a machine made for bending sheet metal. Considering the fact that such a machine is usually very large and almost always extremely expensive, we will dispense with it. Okay, if you have a metal brake, then you can skip "Brake Time."

We will use the next best thing — a "jig" for making bends in sheet metal (Figure 14). To make the jig, I use whatever tools and materials are available and are best suited — such as a vise, vise grips, clamps, chunks of wood, chunks of metal, screws, etc. These are tools that apply themselves very well to being part of a jig.

For a simple box shape, I mostly use my vise. It is made of metal and can grip a flat sheet (metal or plastic) without letting it slip while being bent.

Slippage is probably the number one cause of misalignment. You can also use a clamp or a Vise Grip plier to hold and bend your piece (Figure 15).

Usually, the length of the bend will determine the size of your tool.

The other side of bending is the pushing tool. The vise does the holding and now you have to make the actual bend. The tool that does the bending can be your hand.

On small bends, you can bend it with your hand, but larger bends call for

FIGURE 13. Cut on the solid black line.

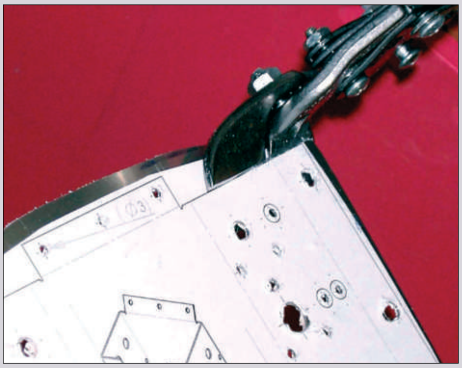


FIGURE 14. Part ready to be bent.

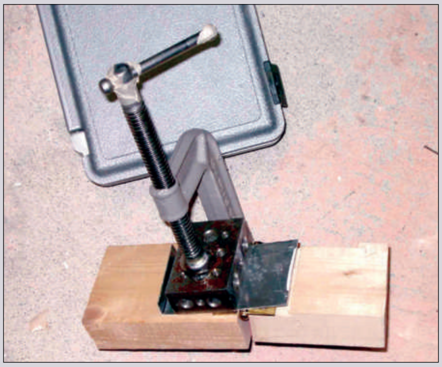
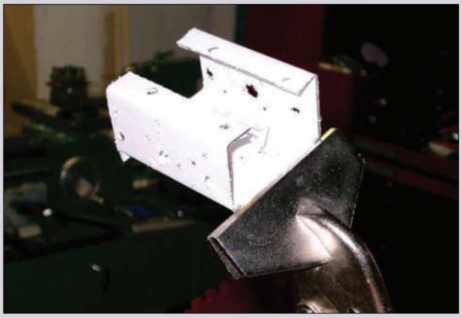


FIGURE 15. Wide nose Vise Grip pliers used to bend the flange with more control and precision.



more strength. A block of wood is my choice of tool for this job. I select the size according to the length of bend.

Apply pressure as close to the bend as possible. The closer you push, the tighter the bend.

Im-Perfect

No matter how hard I try, the bend is never perfect the first time. The adjustment tool for this part is a hammer and a piece of wood (Figure 16). The hammer applies the force and the wood makes sure the force doesn't cause too much damage.

Place the block of wood on the bend and hit the block with the hammer. Examine your work after each hammer blow to make sure you don't overdo it.

With time and some practice, the hammer will just sit under the bench, unused.

Some More Wisdom

Practice, practice, practice, and don't forget safety, safety, safety.

Find some scraps to practice on first. Bending should be the last necessary operation for your sheet metal project. That does not mean it is the last thing to be done. At this point, I inspect, measure, and adjust my work.

When all pieces seem to fit together, it is time for cleaning, de-burring, and assembly (Figure 18). The functionality of the assembly is tested and re-adjustments are made. Are you happy with the results? Does it work smoothly? If yes, then it is time to disassemble, clean, and paint.

I always leave the painting step for last. During the initial assembly and consequent re-adjustments, the surface of your work will undoubtedly get scratched and dented. Keep in mind the fact that painting the holes will decrease their diameter. It may be a good idea to mask the inside of the holes in order to keep the paint from flowing inside.

That's a Wrap

That's it for this installment. Next month, we will build a matching scoop for the chassis and add motors and a controller to make it into a fully functional, competition legal, autonomous mini-sumo robot. SV

About the Author

John Myszkowski worked in the area of electronics and mechanical design in the industrial automation and automotive industry for over 20 years, and loves tinkering. He can be reached through Email at ***john@myszkowski.net***

FIGURE 16. The fold being adjusted.

FIGURE 17. Our mini sumo robot and Peg-Leg, the crawling robot, which needs no wheels, just some wire and plastic spacers. Peg-Leg uses the same chassis.

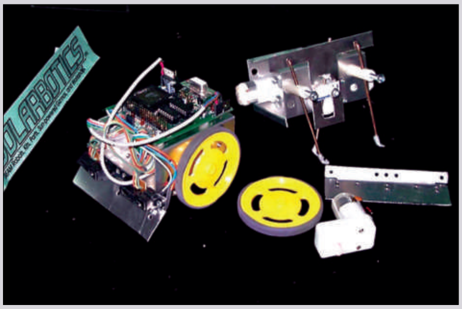
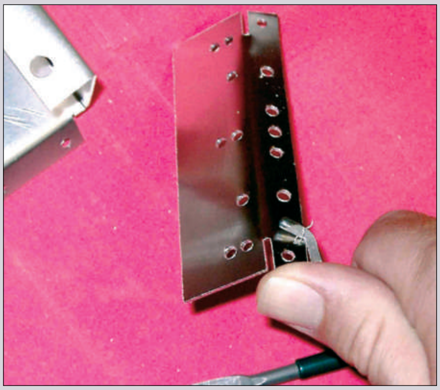


FIGURE 18. De-burring sharp edges.



New Products

ACCESSORIES

The VDS-2200 Video Modem System

The VDS-2200 Video Modem System is used to send video, audio, and power a distance of over one mile by using just one single regular BNC cable. It offers a great possibility to set up a security camera anywhere — even where there is no power supply. In addition, it simplifies the wiring.

For further information, please contact:

Matco, Incorporated

2246 N. Palmer Dr., Ste. 103
Schaumburg, IL 60173
Tel: **847•303•9700** or **800•719•9605**
Fax: **847•303•0660**
Website: **www.matco.com**

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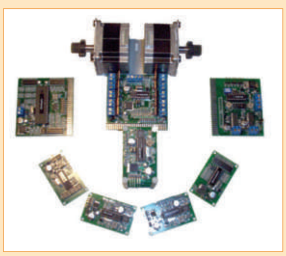
CONTROLLERS & PROCESSORS

Control It All With Super Stepper



A new serial command protocol for controlling everything has been devised by Avayan Electronics. Designed with the goal to control stepper motors, the Super Stepper architecture can easily control other peripherals such as DC motors, RC servos, solenoids, relays, lamps, sensor inputs, and much more. Personal computers, single board computers, microcontrollers, and BASIC Stamps will have a blast communicating to the powerful Super Stepper devices.

The protocol allows for up to 32 devices to be connected on a single serial communication chain. The commands — which are device dependent — offer control features such as speed, direction, position, homing, input sample, etc. Most devices will also include RAM and EEPROM memory space which can be used by the application for storage.

Avayan Electronics is proud to offer the first line of Super Stepper products which they feel will clearly be a milestone of easy robot and automation control. These little boards, and the ones to follow, will work with small to large robotic applications.

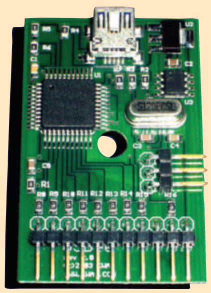
For further information, please contact:

Avayan Electronics

PO Box 994
Webster, NY 14580
Email: **avayan@avayanelectronics.com**
Website: **www.avayanelectronics.com**

Circle #140 on the Reader Service Card.

The USBee EX Experimenter's Boards USB High and Full Speed Development Boards



CWAV now offers the USBee EX family of USB Development Boards. The USBee EX 2.0 supports development of USB 2.0 High Speed devices, while the USBee EX supports USB Full Speed development. Both platforms use the compact development board combined with the USBee Toolbuilder software libraries and drivers to quickly design custom USB solutions. The USBee EX Experimenter's Board is the latest addition to the USBee Digital Test Pod product family.

With USB being the dominant external PC interface, embedded designs are naturally moving to utilize the bus for connectivity. Using the USBee EX Experimenter's Boards, every embedded application can now gain the benefits of the higher data rates (480 Mbps and 12 Mbps), simple installation, and self-powered capabilities without the headaches traditionally found with USB development.

Unlike other USB development systems, the USBee EX Experimenter's Board combined with the included drivers and libraries is a ready-to-embed solution already optimized for size and cost, and can be transferring data in minutes, not days. "The USBee EX Experimenter's Boards give engineers and hobbyists instant access to the ubiquitous USB 2.0 High and Full Speed bus," states Tim Harvey, CWAV's Chief Technical Officer, "which before took board development, firmware programming, driver development, and integration."

The USBee EX Experimenter's Boards are fully compatible with applications written around the familiar USBee Toolbuilder software frameworks used with the USBee Digital Test Pods. The USBee Tool Builder software allows the creation of custom interfacing and test tools using Visual Basic or C. The software for the USBee EX

Experimenter's Board is provided for free at **www.cwav.com**. In single units, the USBee EX 2.0 High Speed Experimenter's Board is priced at $199.00 and USBee EX Full Speed Experimenter's Board is priced at $99.00 Both boards can be purchased directly from the CWAV website, and quantity and educational discounts are available.CWAV's mission is to be the leader in compact and affordable digital electronic test tools. Students, engineers, and technicians currently use CWAV's products in a variety of industries throughout the world. CWAV's headquarters are located in Temecula, CA, with a wide-reaching international presence on the Internet.

For further information, please contact:

CWAV	PO Box 892661 Temecula, CA 92589 Tel: **909•693•3065** Email: **info@cwav.com** Website: **www.cwav.com**

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MOTORS

LO-COG® 26MM Brush-Commutated DC Motors

LO-COG® 26 mm brush-commutated DC motors available from Pittman feature seven-slot skewed armatures for reduced cogging and resin-impregnated windings for enhanced reliability.

These smooth-running and quiet iron core motors can serve as an economical alternative to coreless products. Applications include data storage, medical/biotech, semiconductor, automation, commercial aviation, hobby, and others requiring high performance, long life, and reliability.

LO-COG 26 mm brush motors (Series 8690™) are offered in three lengths (1.798", 1.923", and 2.173") and can provide continuous torque output up to 3.17 oz-in, peak torque up to 20 oz-in, and speeds up to 9,000 RPM.Features include bonded neodymium iron boron magnets to promote enhanced operating performance and diamond-turned commutators for maximum brush life. An innovative cartridge brush assembly reduces audible and electrical noise and significantly improves brush life by maintaining optimum brush force throughout the life of the motor.

LO-COG 26 mm brush motors can be customized with optical encoders, custom cables, shaft modifications, shaft-mounted pulleys and gears, ball bearings, RFI suppression components, and other options to satisfy specific application requirements. All Pittman motor products are subject to automated testing prior to shipment.

For futher information, please contact:

Pittman	343 Godshall Dr. Harleysville, PA 19438 Tel: **877•748•8626** or **215•256•6601** Fax: **215•256•1338** Website: **www.pittmannet.com**

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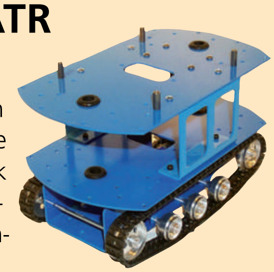
ROBOT KITS

Make Tracks With ATR



Rogue Robotics introduces the new Rogue ATR™ (all-terrain robot) tracked robot base kit. The Rogue ATR's tracks make short work of small obstacles in cluttered classrooms, labs, and home environ-

ments that would bring other robots to a halt.

Rogue ATR features an eight-inch base with rubber tracks, Rogue's universal sensor mount system, dual DC gear motors, extra level capability for expansion, and a 1.1 amp dual H-bridge module. The Rogue ATR is made from the same laser cut aluminum and powder coating as the popular Rogue Blue robot base.

The Rogue ATR has mounting holes for the OOPIC-R, Parallax Board of Education™, and the Rogue OOBoard™. As always, you can add your own mounting holes for your favorite controller board. The Rogue ATR robot base sells for US $124.95. It is also available as a full robot kit bundled with the Parallax Board of Education (US $219.00) or as a Rogue ATR OOBoard full kit with 8.4 NiCad pack (US $259.95).

For further information, please contact:

Rogue Robotics

103 Sarah Ashbridge Ave.
Toronto, ON
Canada M4L 3Y1
Tel: **416 • 707 • 3745** Fax: **647 • 439 • 1577**
Email: **info@roguerobotics.com**
Website: **www.roguerobotics.com**

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TOOLS & TEST EQUIPMENT

The Complete Mill CNC System — Including Computer

For several years, Sherline Products has been offering small, American-made mills and lathes in a "CNC-ready" configuration, which means they are ready for the application of stepper motors and controls made by others. Due to requests from customers wanting to buy a complete system from one source, Sherline has just introduced a CNC package that breaks new ground on several fronts. To eliminate software conflicts and installation headaches, the Sherline package includes a new computer with operating system and software already installed. The driver board is preinstalled in the computer, so all you have to do is plug in the stepper motors, turn on the computer, and get to work.

The other surprising feature is the price, which is just $2,350.00 for the whole system including 5400 deluxe mill, three dual-shaft stepper motors with handwheels for optional manual operation, computer, drivers for four axes, power supply, cables, keyboard, mouse, and preinstalled software. This is less expensive than most systems that don't even include a computer. Customers can add an optional 3700-CNC rotary table and stepper motor ($370.00) to take advantage of the fourth driver already preinstalled in the computer to have full four-axis capability.

The operating system used is Linux, and the CNC software is EMC (Enhanced Machine Controller), an open source program developed by the National Institute of Science and Technology (NIST). This sophisticated software utilizes industry standard G and M codes and also features cutter compensation and backlash compensation. The software can accommodate either inch or metric dimensions. Sherline's standard one-year warranty applies to all components of the new system and one hour of free technical support is also included. Included with the system are CDs for backup Linux and EMC installation, user instructions, and a free copy of the Vector32 CAD program.

For further information, please contact:

Sherline Products, Inc.

3235 Executive Ridge
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THE HUMANOID DREAM

WHERE ARE THE HUMANOID ROBOTS THAT THE WORLD WAS PROMISED IN SUCH FILMS AS "AI," "SHORT CIRCUIT," AND THE JETSONS?

BY BRANDON PHILIPS

They are hidden away...

... Today, they are in the labs of the world's most famous universities and industrial research centers, but a robot created by a team of students from Newberg High School (NHS) and Sherwood High School (SHS) in Oregon might just change all that.

A handful of teenage engineers and their advisors have used available technology to create a humanoid robotics platform that makes the dreams of your childhood a reality. Their story and robot have an intriguing past and a hopeful future that very well could change the current state of hobby robotics.

Big Win for Humanoid Robot at Competition

Terry Coss, the NHS Robotics Team advisor, has created a well-respected robotics program at his school that has been competing at the Robotics International/Society of Manufacturing Engineers Robotic Technology and Engineering Challenge (**www.sme.org/cgi-bin/eduhtml.pl?/educat/srcpg.html&&&SME&**) for several years.

This particular event has been a favorite of Coss and the team because of its backing from a nationally recognized organization, and its plethora of exciting industry backed categories, but more importantly the Robotic Challenge has a focus on the student engineers. The judges interview each team and question them about the engineering processes used, design considerations, and final product. This interviewing portion of the judging weighs heavily into the final score, and gives the students an incentive to learn, innovate, and understand every process used in building the robot. It also ensures that the project was truly student built, but with over 4,000 student hours logged on the project, the team had many topics to speak to the judges about.

For the last two years, the team has gone to the competition with a new robot concept, a mobile humanoid with an attitude and personality that people can relate to, based on technology and processes available to anyone.

That concept is now a reality, and the response from the public and judges has been one of excitement, delight, and amazement. These emotions are roused through the human qualities that the hardware and software attempt to replicate, from the baby blue USB 2.0 cameras to the slight and silent movements of the eyelids, much thought has gone into making Bob a "living machine." Although Bob Version 2.1 (V-2.1 for short) entertained the crowd and judges, it was the design, precise manufacturing, and easy-to-use software that earned Bob and team Judges Choice, the best in competition award.

Designing the New Machine

The team had a bit of a head start this year thanks to V-2.1's earlier cousin, Bob Version One. The majority of the experimentation and engineering for the knees, arms, ultrasonic sensor, computer, and power systems was done before V-2.1 even began, but this didn't mean the V-2.1 was going to be a carbon copy; the team had many improvements in store for Bob. In fact by the time the improvements were implemented, only four out of 400+ individual parts were copied from the original design.

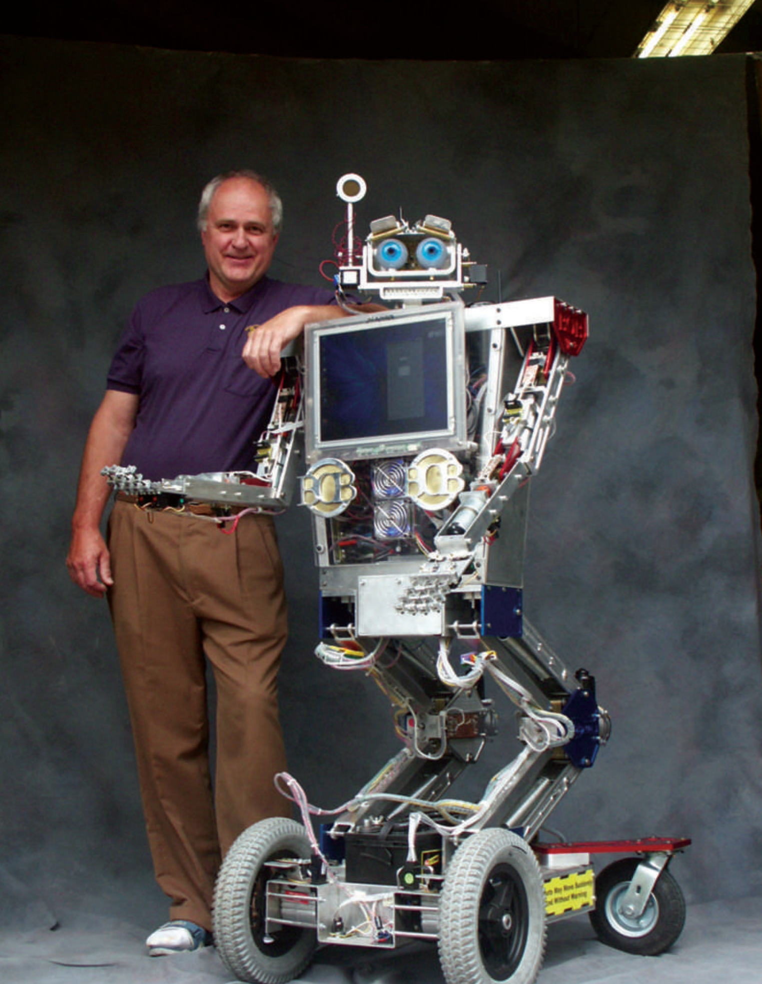
In this second version of the robot, the team began improving from the bottom up and embraced overbuilding, part standardization, manufacturability, power system isolation, and object oriented software design. These early design decisions gave the team focus, and a feeling for the real pressures of commercial level engineering work.

Brandon Philips and Ryan Miglavs began working on the Bob project. The partnership continued into V-2.1, and the two programmers worked on improving and extending Bob's software in a big way on the new version.

Working Out the Mechanics

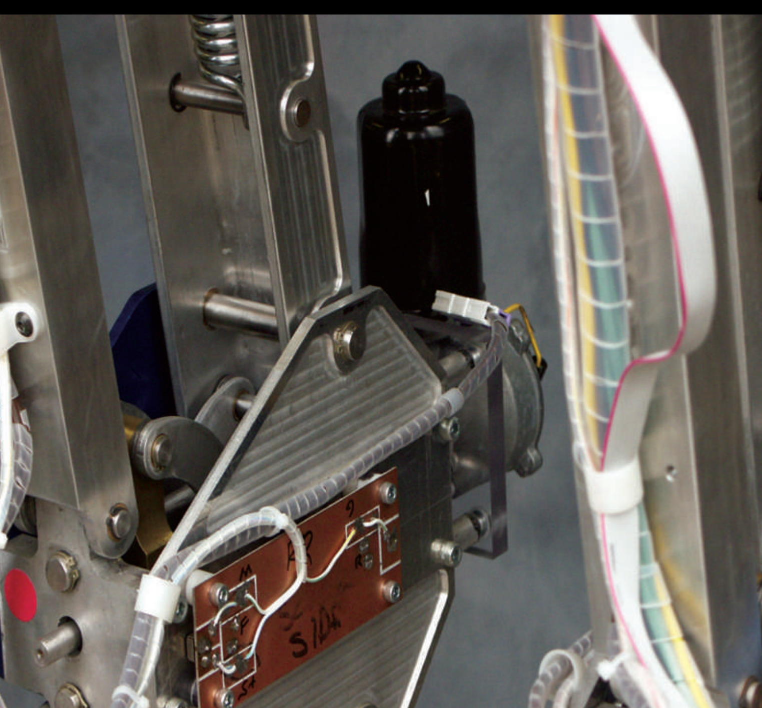
Making the broad mechanical design goals a reality began with a daily brainstorming session where every student submitted ideas and suggestions (even the software guys), then those ideas were massaged into a CAD drawing. Inevitably something would not work with the prototype, and again more brainstorming was done, the design was improved and put through a well-established manufacturing process. The amazing part is that the team was able to brainstorm in the afternoon and have parts finished the next day.

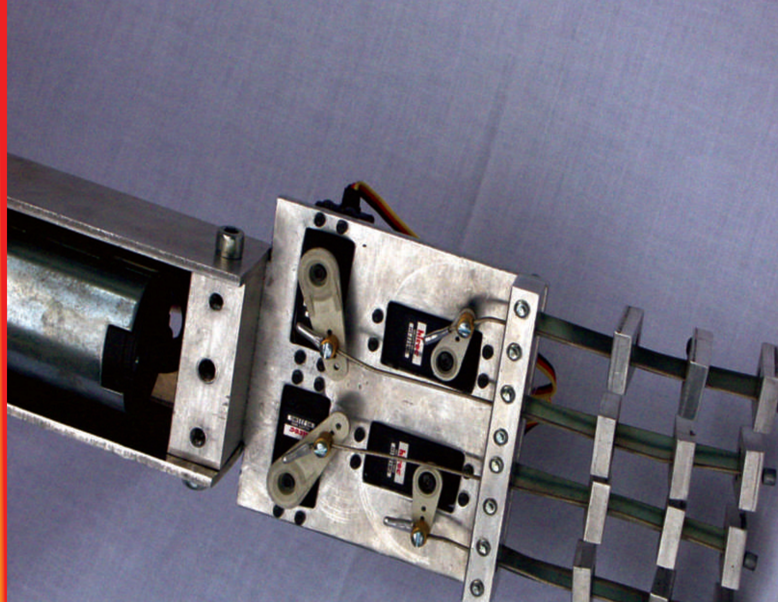
Manufacturing in this speedy process begins with the underclassmen that cut and de-bur the metal, then hand it off to the upperclassmen that use either a CNC or hand mill to create the part. Then, once again, the younger students de-bur and polish the part. This process allows everyone to have a niche based on his or her experience level, and for training to happen day in and day out as the underclassmen learn the job above them from observing. It also avoids heart-wrenching accidents — like an underclassman tapping a hole in the wrong location on a part that took all day to fabricate.



Terry Coss is the Newberg High School robotics team instructor.

The knee joints are tracked by linear potentiometers, and are moved with a 12-volt windshield wiper motor running at 24 V.

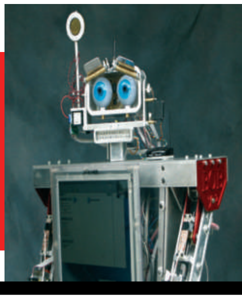
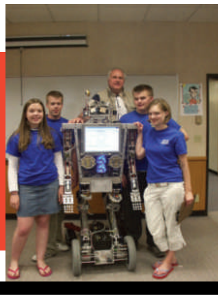


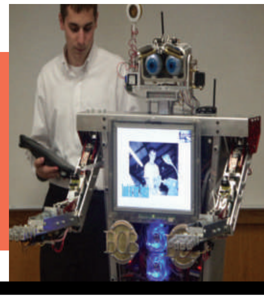


Bob's fingers are made of spring metal that are pushed and pulled by R/C servos.

Many pieces of aluminum on the robot have extra detail to give the robot texture and visual interest. The blue plate was milled at NHS and anodized off-site.

The black disc is the optical encoder for the base, and the Z-shaped bracket holds an infrared distance sensor.




Tricks of the Trade in Robot Manufacturing

Covering every major mechanical design element is beyond the scope of this article, but the general design tactics the team used and some helpful tips can be shared.

As a general rule, the team has learned to simplify part fabrication and assembly by standardizing nuts, bolts, bushings, steel shafts, and methods of locomotion used throughout the robot. Related to this, the team has dedicated a good portion of time engineering all of the parts so that they are assembled and bolted onto the robot as modular units, as opposed to permanently welding them.

The shafts that are used to allow articulation on the robot are either 5/16, 1/2, or 3/8 inch steel shafts that rotate inside a bushing. To fit a bushing, a hole is drilled .001 inches smaller than the bushing (known as an interference fit), then the arbor on the mill is used to press it in.

This crushes the bushing, giving it a nice tight fit. Then the internal diameter is reamed out to .001 or .002 inches larger than the shaft to give a snug fit.

To hold the shafts into the bushing, the team found C-clips to be a fast, sturdy, and economical fastening device, and they are used extensively on the robot.

Making these joints come to life required a source of linear motion that was powerful and compact. The team tried all of the traditional methods including bicycle and photocopier chains, gears, and cog-belts but in the last two years ACME screws have truly proven themselves as a great way to convert the rotational motion of an electric motor to linear motion.

But, there is one problem with ACMEs: the shaft must line up perfectly with the motor, or a variety of bad things will happen. To fix this, the team found the orange Lovejoy couplers you see in the photos extremely useful, because they allow for fast motor replacement and tolerate a small amount of misalignment.

Making Bob Come Alive

The mechanical works of Bob are quite impressive, but without the electronics, V-2.1 is just a very large action figure. Since the NHS robotics program began in the late 80s, technology has come a long way.

Just 14 years ago the team was using toggle switches and DC motors to run electronic arms, a decade ago Fascinating Electronics Experimenters control boards, and three years ago PLCs were used on their winning Jack in the Box (see *The Nuts & Volts Of Amateur Robotics, Supplement #1*), but the Bob series has taken a new direction.

V-2.1 and his earlier cousin embed an ATX PC inside of the torso. Last, year the team used two general-purpose control devices called Experimenters from Fascinating Electronics (**www.fascinatingelectronics.com**) that provided DC and stepping motor control, analog and counter/timer measurement inputs, digital I/O, and a high current relay. These devices are controlled via simple commands output through a serial port and are used to drive a variety of student-built motor drivers and an ultrasonic sensor.

Although this solution worked, it had a few limitations: closed loop control had to be done by the PC, high current drivers were hand wired, and a common ground was shared between the high current drivers and the computer.

To solve this the team tested a new line of prototype devices from Fascinating Electronics that were created just in time for Bob 2.1. These units provided optically isolated electronics logic, closed loop motor control, high current drivers, and a variety of other features that made controlling all of the robot's motors and R/C servos a breeze. But the favorite feature of the team was the USB interface that made adding a new device to the software easy and intuitive (after the team's programmers wrote a Microsoft Windows® control library for the devices).

The modules from Fascinating Electronics used on V-2.1 include two 16-channel R/C servo drivers, two high current dual motor drivers, and two low current dual motor drivers. And even though each module is feature-loaded, they still come in a compact footprint; the servo and low current drivers measure 3"x5" inches while the prototype high current driver is a bit larger.

These Fascinating Electronics modules also provide sensor inputs. The low and high current drivers (LCD and HCD) provide closed loop control of the potentiometer-tracked arm and leg joints. The HCD used on the wheel base counts and times the 50 clicks-per-revolution timing disc that is attached to the axle of each drive wheel to provide the programmers the necessary information for proportional, integral, derivative (PID) control of wheel movements.

The tried and true Experimenter controls the ultrasonic range finder, which is used to create a safety zone around the robot during his presentation.

These new drivers also provide two features that every

electronics hobbyist can appreciate: cable management and a global disable. To tidy up cabling, every driver comes with a 1" by 1.5" terminal block that connects to a convenient 10-pin locking ribbon cable header.

This terminal block makes it easy to attach sensors that are several feet away from the module and can be used to communicate four analog inputs, four digital inputs, +5 volts, and ground.

The R/C Servo driver has another type of terminal block that can be used to carry the pulse, +5, and ground to eight servos.

The global disable input is another nice feature that was provided by the drivers. This input is wired to a latching emergency stop switch and Lynx wireless receiver on V-2.1. Pressing the emergency stop switch or using a wireless keyfob cancels all commands to the robot motors.

Adding the Personality with Software

Bob was the first project in which NHS had to call for outside help on the software portion. At the time (2001), Coss simply could not find a good programmer from his district. To solve his software problem he called up Sherwood High School's Industrial Arts and Robotics instructor John Niebergall.

A partnership was made between the two small districts, and Brandon Philips and Ryan Miglavs began working on the Bob project. The partnership continued into V-2.1 and the two programmers worked on improving Bob's software in a big way on the new version.

On V-2.1, an object-oriented design was enforced and many software technologies were used on the project. The first design decision was to write the critical MS Windows drivers for the Fascinating Electronics modules in C++, but to use Visual Basic for doing the graphical user interface and scripting.

The advantage of this design is the software that should be fast, stable and constant is compiled — while the variables and scripts that need to be constantly tuned are written in a scripting language, making prototyping fast and easy. Interfacing these two very different languages required using the Common Object Model (COM) and Active Template Library (ATL 3.0) by Microsoft.

These two technologies allow for the writing of objects in C++ that can be both created, destroyed, and their methods called from other languages.

A few toolkits were also leveraged to create the software. First, the students used the Microsoft Speech Application Programming Interface version 5 (MSAPI 5.0) to create the robot's voice. This toolkit is pretty much a plug and play feature; you install it, load it into your project, and you are done. It was a joy to work with. Communication with the Experimenter was done via the ActiveX control MSCOMM, that gives a programmer total control over communication with serial devices.

Covering the entire design and specifics of the software is beyond this article's scope but you can find the source code and documentation at **www.experimentsindigital.com** Also at that web address, you can read about the upcoming Linux port that will include mapping, vision processing, Python scripting, autonomous roaming, and more.

Bob V-2.1's Future

Fascinating Electronics believes the robot designed by the students of NHS and SHS is something that many hobbyists and students would like to have. At this time, they are developing a kit derived from Bob V-2.1 to be named "ZedBot."

This company's commitment to the project, and their plan to take the student's design commercial, is a true testament to the NHS and SHS robotics programs. **SV**

About the Author: Brandon Philips is a freshman computer science student at Oregon State University. He recently finished the Linux kernel drivers for ZedBot and is working on a new Python API. He is looking forward to working with a growing community of ZedBot developers.

He can be contacted via Email at **brandon@clevercoder.com**

Robytes

Welcome back to our little collection of random bits of robot news from around the world. Got a good story on robots? Email me: news@robotics-society.org If you'd like to get even more robot news delivered to your in-box (no spam, just robo-news) drop a line: subscribe@robotics-society.org

— David Calkins

Robot Helicopters Under 10 Grams!

Photo courtesy of David Calkins

Microbots just keep getting smaller. Back in November, I had the great fortune of going to Tokyo for the International Robot Exhibition, and Epson was debuting their new mini-copter, which they're calling μFR ("Micro Flying Robot"). This amazing gizmo weighs only 8.9 grams, can lift up to 13 grams, is smaller than 100 cubic millimeters, and is controlled wirelessly via Bluetooth (finally, a use for it.)

The micromechatronics levitator was a huge crowd draw and with good reason — it was light, agile, and well ... really cool. Unlike most helicopters which use a single main rotor and a collective rotor for stability, the Micro Flying Robot uses concentrically located contra-rotating propellers powered by an ultra-thin, ultrasonic motor — with the world's highest power-to-weight ratio — and balances in mid-air using a linear actuator.

How cool is this little critter? It made the Guinness Book of World Records.

http://robotics-society.org/servo/?i=021

Attack of the Robot Lobsters!

Photo courtesy of Brooklyn College

Okay ... This goes too far. I'm all about robots replacing sniffer dogs and house flies, but that's because I don't enjoy eating either of them with melted butter and lemon. Brooklyn College has made robotic lobsters with plastic cylindrical bodies, large wheels instead of legs, and fiber-optic antennae. Apparently, real lobsters have a very advanced ability to sniff out individual odors and where they've come from.

These robots mimic the real lobsters abilities to trace chemical smells, no matter how strong the current or which direction they come from. Brooklyn College research scientists Frank Grasso and Jennifer Basil co-developed these robots and successfully tested them recently in the Red Sea.

The bots will be used to localize sources of pollution and detect unexploded mines, but won't impact the real lobsters habitat — nor replace them. Pass the lemon.

http://robotics-society.org/servo/?i=022

Robots Get Their Own Hall of Fame

Photo courtesy of LucasFilm

Why should baseball players get all the attention?? Robots have been around since ancient times (golems, automata, etc.), and yet they get no respect.

Well, that's finally changed. Carnegie Mellon University, that bastion of robot research, has opened its own hall of fame for our mechanical friends! Thoughtfully, they're giving room to both real robots and mythical ones. With a notable panel including such experts as Rodney Brooks, Arthur C. Clark, and Will Wright (Will always gets the best gigs ...), they've kept the initial inductees down to four — two from the fictional world and two from the real world. HAL 9000 of 2001 fame made it in along with one of my all time favorite robots, R2-D2 (from a little known science fiction movie from the 70s.) On the other end of the spectrum, the first "real"

robot, Unimate, was inducted — Unimate was the first industrial robot, and is the grandfather of the robots that build your gas-guzzling SUV. Also inducted was Mars Pathfinder Sojourner Rover, the super successful robot that brought us those amazing images back from Mars. Barry Bonds eat your heart out.
http://robotics-society.org/servo/?i=023

"Thinking" Robots at JPL

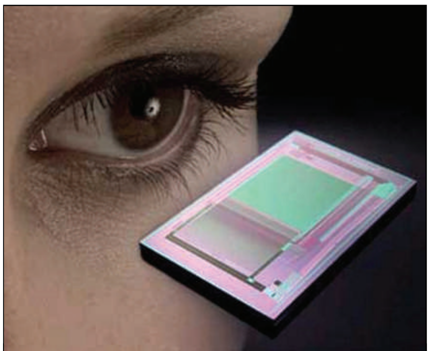


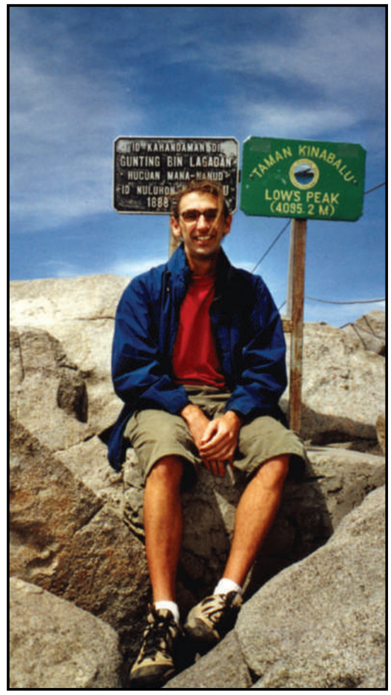
Photo courtesy of Jet Propulsion Laboratory

I'm sure this will make Bill Joy's day. A bunch of clever folks at the Telerobotics Research and Applications Group at NASA's Jet Propulsion Laboratory are writing artificial intelligence programs that will give robots the kind of skills that humans use in their thinking process.

"What we hope to do eventually is get robots to be more independent and learn to adjust their own programming," says Barry Werger, JPL robotics engineer. Right now, most robots are programmed very deliberately with little ability to change, should they encounter an unexpected problem (such as a big rock in their path, or an irate editor).

New behavior-based control programming lets the robot move around a problem and then continue on with its regular instructions. Using both fuzzy-logic and neural networks, the robots can both store experiences and later use that knowledge to solve problems it has never before encountered — much like we humans learn as we grow up. Too bad they'll get to go to Mars and you won't ...
http://robotics-society.org/servo/?i=024

Just Like Your Mom!



Most humans rely on multiple sensors to get around. Eyes, ears, and touch (including feeling a breeze on your neck) all contribute to how you know where you are and where you're going (in my case, I'm going nowhere fast, but that's a different column).

Robots, on the other hand, can rarely rely on so many sensors. And even when they have that many, it's very hard for the processor to compute all of the data accurately.

Researchers at the University of Maryland, led by Cornelia Fermueller, have developed the "Argus Eye" (named after the Greek all-seeing god). This eye can see in all directions, and radically improve robot performance.

Not only can it give data on where a robot *is*, but also on where it's *going* — based on the feedback of which images are getting smaller and which are getting larger — and at what rate.

This type of sensor can greatly

reduce the costs of manufacturing robots, as well as dramatically improve performance. You'd no long have to be careful when walking behind your robot, for example, and it could also more easily tell if you were slowing down behind it or just walking through.

Of course, moms have always had eyes in the backs of their heads — now put that cookie back in the jar until after dinner.

http://robotics-society.org/servo/?i=025

For i=1 to 3; print "Gobble"; next i

Photo courtesy of Custom Robotics Wildlife

Thanksgiving and Christmas have always been gorge fests centering on tryptophan-overload via that slow-roasted delicacy we like to call "editors" erm ... "turkeys." But how to catch a turkey, you might ask? Why, a turkey robot, what else? And once you've got your own turkey, I'm sure you could use the robotic turkey to feed your Aibo. But I digress. In the "I couldn't possibly make this stuff up" file, a Mosinee, WI company — Custom Robotic Wildlife — makes robotic decoys for hunting, which greatly improve your odds of shooting the tasty fowl. They move their heads, tails, and can even be seen strutting on a swivel base. If you've had your fill of holiday turkey, they also make robotic deer, bear, elk, and moose. No word yet on when the animatronic cranberries will be available ...

http://robotics-society.org/servo/?i=027

Just Like Your Driver's-Ed Teacher

French researcher Thierry Fraichard and Japanese researcher Hajime Asama have designed a collision-avoidance system dubbed the "Inevitable Collision System," which aims to radically improve a robot's ability to not whack into your ankles while fetching you that beer.

The system works by monitoring objects and determining an "exclusion zone" around itself and its current motion vector.

This exclusion zone is the area where collisions are unavoidable (like the only bathroom at a frat party). The program is constantly checking all objects, and itself, while updating the robot's potential trajectory.

This is done in real time, and as such, can significantly reduce the likelihood of the robot colliding with any other objects. Which might not be the point if you are at a party ...

http://robotics-society.org/servo/?i=026 SV

BIO-FEEDBACK

Continued from Page 7

Dear *SERVO*:

Enjoyed the first two issues greatly. But I have one suggestion to help out on the readability of *SERVO*. While they look great "artistically," pages that have text printed on a "picture" background (p. 40-46, Dec. 2003) are hard to read. Also, text printed in color on a colored background (p. 29, Dec. 2003) is hard on the eyes. I like color, but for reading text, black text on white background is hard to beat.

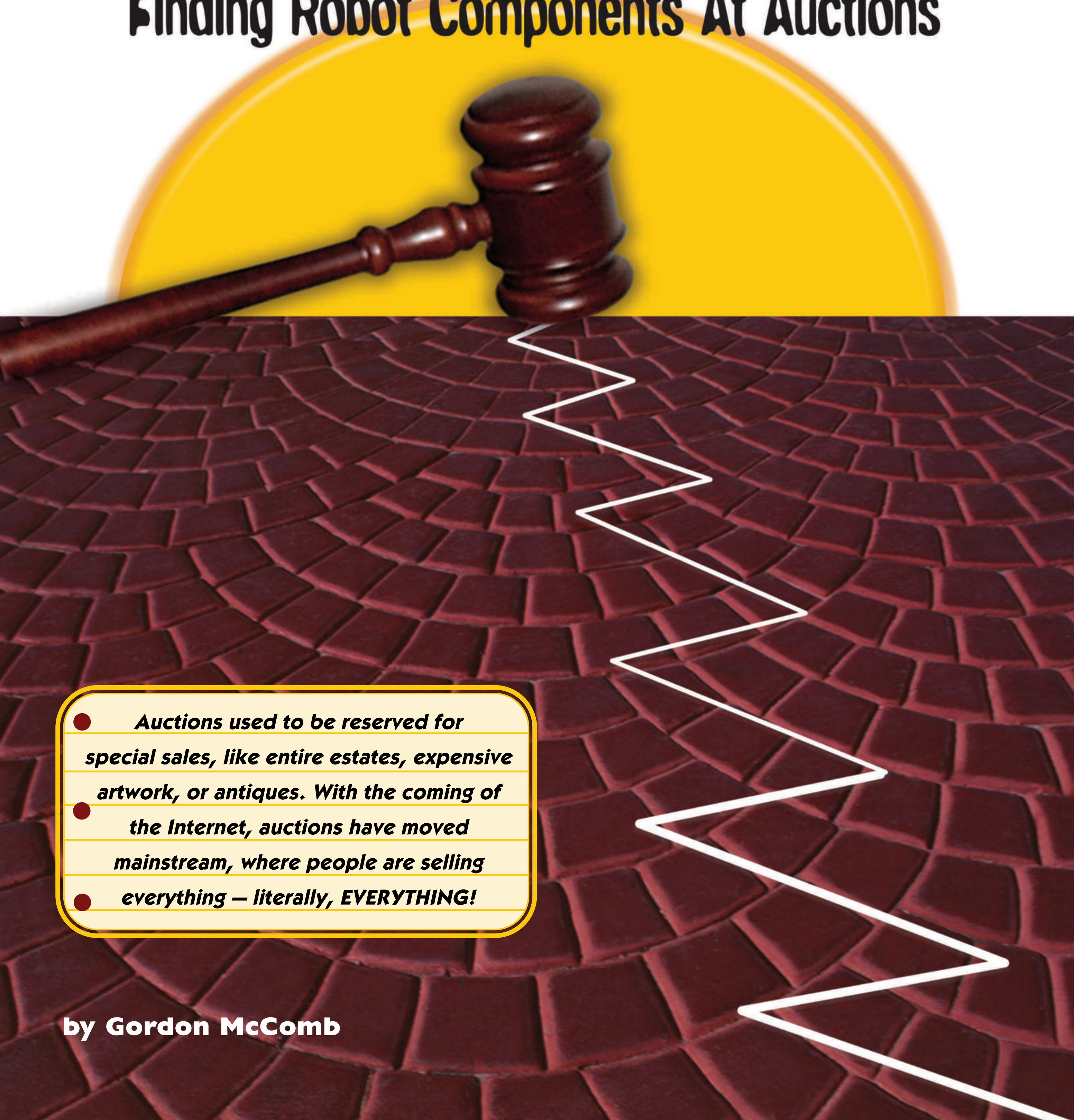
Keep up the great articles.

Joe Fishback
via Internet

Robotics Resources:

Going Once, Going Twice:

Finding Robot Components At Auctions



Auctions used to be reserved for special sales, like entire estates, expensive artwork, or antiques. With the coming of the Internet, auctions have moved mainstream, where people are selling everything — literally, EVERYTHING!

by Gordon McComb

In this month's *Robotics Resources,* we cover auctioneers that provide item descriptions or even complete details online. Listings include auctions held by the US government (the world's largest purchaser of goods), online giant eBay (the world's largest auctioneer), and others.

WHY BUY AT AUCTIONS?

In traditional retailing, the seller sets the price. The fine art of haggling notwithstanding, the customer either buys the product at that price, or moves on. The benefit of a fixed price is that, at the time of purchase, both buyer and seller have implicitly agreed on the main point of the transaction: how much it costs. This system works best for products that are available in quantity.

With auctions, the buyer sets the price, though the seller can specify a minimum amount he or she is willing to settle for. In almost all cases, the item is one-of-a-kind — such as a painting, a piece of furniture, or a used oscilloscope. With only one to choose from, prospective buyers might be induced into "fighting" for it, and the highest bidder wins it.

There are many kinds of auctions. The public auction is perhaps the most well known. In a public auction, a fast-talking auctioneer introduces each item, sets a minimum bid amount, then calls on the participants to better that bid. Everyone knows what the current bid price is. When no one is willing to bid higher, the auction is closed, and the item is awarded to the highest bidder.

In a closed or sealed auction, prospective bidders determine the value of items they wish to purchase, and submit private bids for later consideration. If there's more than one bid, the item is awarded to the highest bidder. Buyers don't know what others are bidding, or even if other bids have been placed. This type of auction is common in selling government surplus, and can be more risky than public auctions. The tendency is to bid too high, and spend too much.

Most online auctions, like eBay, are a form of public auction where the current high bid is known. The Internet is the mechanism that brings together seller and bidders. These days, eBay and many other online auction services also support traditional retailing, where a seller offers items at a fixed "buy it now" price. These sales transactions are clearly marked as such.

For robotics, auctions can provide inexpensive test equipment, tools, construction materials, batteries, motors, and more. At any one time, for example, there are hundreds of robotics-related items available on eBay, from DC gearmotors, kits, books, microcontrollers, general electronic components, you name it. The savings can be significant, but you must be careful. Following are some "gotchas" you should be aware of:

1. Most auctioned items are sold as-is, and one person's high bid may be another person's junk they're been trying to unload. Do not bid on any auction unless you know exactly what you're buying, no matter how attractive the price. This applies particularly to government auctions, where online details are scarce, and the condition of the item is only marginally described.

2. Shill bidding has long been the bane of public auctions. The problem exists in online auctions, as well. With shill bidding, someone working with the seller jacks up the high bid, in hopes of raising the bids among legitimate buyers. If the shill's bid is the highest, the item "closes" (the auction is over), only to re-appear hours or days later in a new listing.

3. Online auctions have created a new phenomenon called "sniping," where a buyer waits until the last minute to enter a bid, in the hopes that other bidders won't have the opportunity to outbid them. A feature available on eBay and some other online auctioneers is proxy bidding, where you can set a maximum amount, and the system will do the bidding for you. Most seasoned online buyers use proxy bidding to avoid the impulse of overbidding at the last minute.

4. You have a reasonable chance of getting what you pay for when buying at public and sealed auctions. For online auctions, there is a risk that the seller will take your money and never deliver the goods, or send you defective merchandise you can't return. A user feedback system, like that on eBay, helps steer you away from the scamsters, though a few con artists have been able to manipulate the system.

5. Sealed auctions are usually closed many days, or even weeks, after you place your bid. If you won the auction, you must come back to collect the items. Few will ship to you, unless shipping is otherwise arranged.

DRMS

DRMS stands for Defense Reutilization and Marketing Service, an agency of the US government (at least for now) that sells stuff back to the taxpayers who already paid for it to begin with. The government calls it "surplus," but it can be new or used, in perfect or in junk condition. Prices are typically pennies on the dollar, and goods are typically offered as sealed bids.

(By the way, you'll also see the notation DRMO. That stands for Defense Reutilization and Marketing Offices, the name the government gives to each local DRMS field office.)

What can you get with government surplus? If you're lucky, you might find a Jeep for $22.00, but more likely, you'll find reasonably good deals on motors, test equipment, tools, computer gear, and other electronics. You won't be able to purchase entire Titan missiles from Uncle Sam, but you might get at auction some of its non-classified subsystems. (They usually destroy the

classified stuff, though sometimes a little bit of it gets out to the public.)

In the old days, government surplus was sold by the pallet-full at depot stations around the country — often, but not always, at military bases. Now, the auctions may take place on base, or more often than not, over the Internet, or at a private salvager's lot. With the latter, the government has handed over the details of the auction to a private company; the company handles all the financial and material transactions, taking a service fee for doing so.

An outfit known as Government Liquidation, LLC, handles much of the surplus sales for the US government. Their website — **www.govliquidation.com** — should be your first stop for any government surplus auction you may wish to participate in.

The process is fairly simple: First, you register with the site, providing your Email name and physical address. You then cruise the listings. Like all auctions, be sure you're serious about buying before you bid. And unlike eBay and most online auctions, the typical government auction is sealed or closed (though some are open), and you don't get to see what others are bidding for the stuff you want.

This can be a disadvantage or an advantage, depending on how you bid. One approach: Consult the purchase price amount, which is usually indicated in the auction listing. Then base your bid on some percentage of this amount, say 10 or 15 percent. This assumes the item you're bidding on is in good, working order; if it's damaged or non-working, even if listed as repairable, you'll want to offer less than your usual.

If you tend to win every bid, you're probably paying too much. If you win too few, consider upping the percentage. In all cases, be sure you can arrange for the pick-up of the item(s). It does no good to win an auction for stuff that's halfway across the country, if you have no way to get it.

A CLOSER LOOK AT AUCTIONS ON EBAY

Buy used. Buy new. Buy junk. It's all available on eBay, the world's largest online auction site. What you get all depends on how careful of a buyer you are. eBay categorizes their auctions. Among the most helpful in amateur robotics is the hobby and craft categories. You can locate categories of interest on eBay at **pages.ebay.com/buy/index.html** then find the link for Category Overview. This page (the URL tends to change) lists all the categories on eBay in hierarchical order.

Some of the main and sub-categories of interest are:

- **Model RR, Trains** — Model trains and accessories
- **Arts & Crafts** — Painting, scrap booking, ceramics, handcrafted arts, more
- **Models** — Plastic, metal and wood kits, model-making supplies
- **Radio Control Vehicles** — Radio-controlled cars, boats, and aircraft
- **Supplies** — Art supplies and more

If you've used eBay before, then you know all the details. If you haven't used eBay, keep the following in mind:

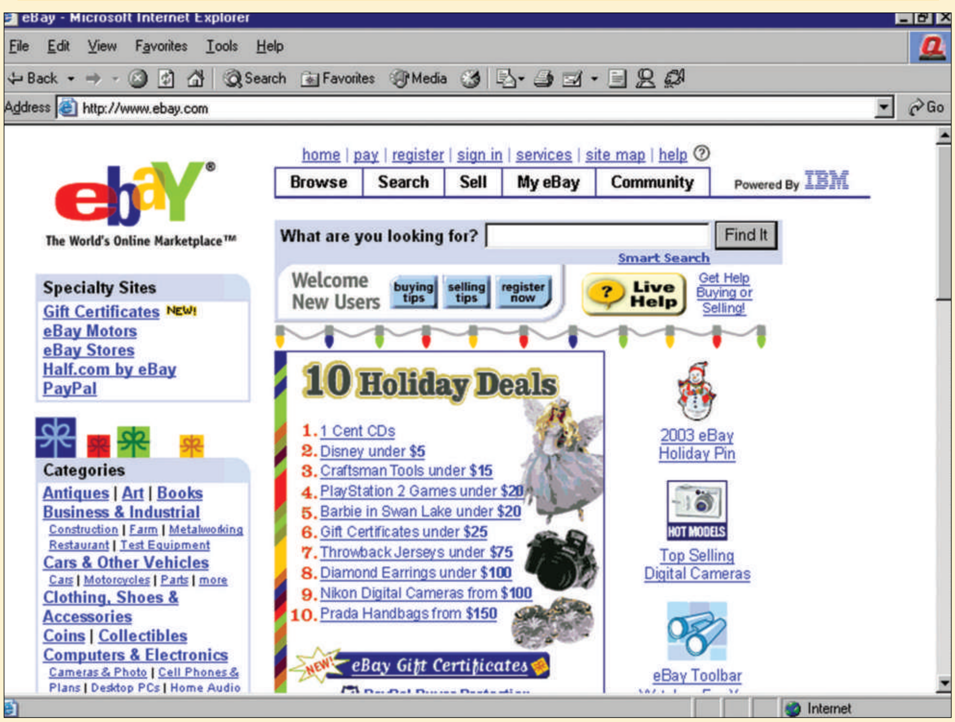
1. You must sign up first before you can bid on any auction, and you must be 18 or over to sign up.

2. Don't bid unless you are willing to spend the money. eBay lets sellers write negative comments about customers who don't pay up. (As a buyer, you can also write things about the sellers you've dealt with. This ensures everyone plays fair.)

3. Read the item description carefully before bidding. Know exactly what you are getting before you bid.

4. If you have any questions, Email the seller. If the seller does not respond, do not bid!

FIGURE 1 King of the online auctioneers — eBay. You can search for items by name, or browse categories.



5. Double-check shipping and handling charges. Some sellers on eBay charge excessive handling, and make much of their money that way. Don't be a sucker.

6. Compare the going price for the item you're bidding on against other current auctions, if any. You can also compare the final high bid priced using the Completed Item search option.

7. Use proxy bidding to set your "best and final" high price. Decide the maximum amount you want to pay for an item, then stick to it. Set this as your high price; eBay will automatically ratchet up your bid, up to your maximum, if others bid against you. Refrain from getting into "bidding wars" at the last minute and going over your maximum.

As noted above, it's quite common to be "sniped" at the last-minute by high bidders. They wait until the auction is about to close, then place their bids, hoping no one outbids them in the final seconds. Don't `get mad and vow to do the same yourself next time. You're bound to over-bid.

SOURCES

Amazon Auctions
www.amazon.com

One of many "stores with a store" at Amazon, here you can find general merchandise in over a dozen main categories. Some robot-related items, such as tools. Many of the items listed are new, and come from small retailers selling through Amazon.

DoveBid, Inc.
www.dovebid.com

Industrial equipment auctioneers. Auctions take place worldwide, but are coordinated through the Internet. Some auctions are held at a specific physical location, but others are webcast. You can participate from the comfort of your office chair. Dovebid specializes in large auctions, including entire factories of equipment. Occasionally, they offer individual items, but these are usually high-end and specialized.

FIGURE 2 **FirstGov.gov** is a portal to many US government auction sites. Be sure to check out the help pages and FAQ for useful information about bidding.

DRMS
www.drms.com

This is the "master federal directory" of US military and related government auctions. Straight from the horse's whatever. It's the place to obtain original US government surplus property. You can find some real bargains here, but don't expect the search to be easy. In addition, auctions of government goods are seldom "by the piece," but rather by the box, case, or pallet. Be prepared to purchase a pallet of 14 oscilloscopes, all in varying condition, not just one.

See also: **www.drms.dla.mil** and **http://wex.drms.dla.mil**

eBay
www.ebay.com

Online auctions. You can search for what you want, or browse by topics. Here are some topics where robot parts and information can often be found (additional "specialty" categories can be found under most of these, as well):

- Books: Textbooks, Education: Engineering
- Books: Nonfiction: Instructional
- Business, Office & Industrial: Industrial Supply, MRO
- Business, Office & Industrial: Electronic Components
- Toys & Hobbies: Hobbies & Crafts
- Toys & Hobbies: Hobbies & Crafts: Radio Control

FedSales.gov
www.firstgov.gov/shopping/shopping.shtml

FirstGov.gov is the official US federal government portal for all government asset sales worldwide. The site includes links to surplus, art, books, even NASA surplus (sorry, no used Space Shuttles available at this time). A search engine is provided at the site to aid in locating the kinds of products you're interested in. But don't expect eBay here ... Uncle

Do's and Don'ts for Buying Mail Order

Online auctions are basically a form of mail order. And while it may seem daft to "explain" how to buy mail order, every year thousands of people get cheated out of millions of dollars. So for reminder's sake, here's a list of do's and don'ts when conducting business by mail.

Do. . . . .

- Understand exactly what you are buying, when delivery will be made, and how much you're paying before sending any money. Sounds simple enough, but it's easy to forget the small stuff when you're excited about finding goodies for your robot.
- Favor those sellers that provide a mailing address and a working phone number for voice contact (not just fax). Sellers without one or the other aren't necessarily crooks, but lack of contact information just makes it harder to get ahold of someone should there be a problem.
- Be wary of individual companies that advertise by sending unsolicited "spam" via Email. Avoid following up on online auction listings sent to you as bulk Email.
- Verify shipping charges, handling charges, and service fees before finalizing the order. These costs can significantly add to the price, especially for small orders.
- Check out the seller bidding a significant amount ("significant" is up to you; it might be anything over $500.00, or it might be anything over $35.00). Check for a poor rating with the Better Business Bureau (or similar institution for those outside the US) in the company's home town, in the appropriate newsgroups, or in online chat rooms or bulletin boards.
- Determine added costs for duty, taxes, and shipping when buying internationally.
- Carefully examine your credit card monthly statement for improper charges.

Don't. . . . .

- Give your credit card number via Email, or on a web page order form, unless you know the communications link is secure.
- Buy from a source unless you feel very comfortable you can trust your money with them.
- Use a credit card to pay for goods from a company you have not yet dealt with, if sending a check or money order is just as easy. This limits the exposure of your credit card accounts to possible Internet fraud.
- Send money to foreign companies unless you're positive they are safe bets. While you're checking them out, be sure they will ship to your country.

Should you have trouble with any mail order merchant, online auction or not, (and you or the business is in the US), the following two organizations might be able to help you resolve the matter:

Better Business Bureau System
www.bbb.org

National Mail Order Association
www.nmoa.org

eBay and other online auction sites also provide their own feedback mechanisms for reporting possible fraud.

Sam himself designed this site, and it can be difficult to find what you want.

Hint: Look for the By Agency search links under Auctions of Government Property, and then choose from among these most-likely candidates for robotics goodies (note: names can change to protect the guilty parties, so be prepared to do a little sleuthing):

- DRMS — Public Sales
- GSA Federal Supply Service (FSS)
- Federal Surplus Property Acquisitions
- NASA Surplus and Sales
- NASA — LaRC Surplus Property Program
- Parcels, DoD Base Closing Property Development Site

See also the links under Supplies & Equipment — Surplus. Maybe no Jeeps for $22.00, but probably some oscilloscopes for $22.00, or even less.

Government Liquidation, LLC
www.govliquidation.com

US government surplus auctioneers. Most auctions are by the lot, meaning they sell a whole kettle of

FIGURE 3 Jewelry, fine art, even sports cars can be found on the US government's GSA Auctions site. They also sell items of interest to robot builders, like motors and test equipment.

stuff at a time. Sometimes what's in the kettle is related, but other times it's not. If you're looking for that oscilloscope, be prepared to also buy an office chair, maybe an old copier, and 1,000 ballpoint pens. You never know.

GSA Auctions
gsaauctions.gov

Online US government surplus sales. As indicated on the website, they offer Federal personal property assets ranging from commonplace items (such as office equipment and furniture) to more select products like scientific equipment, heavy machinery, airplanes, vessels, and vehicles. GSAAuctions.gov's online capabilities allow GSA to offer assets located across the country to any interested buyer, regardless of location. GSA auctions also include seized and forfeited property, so you'll run across fur coats, diamond jewelry, and fancy carpets.

Internet Auction List
www.internetauctionlist.com

Link lists for local and online auctions.

UBid
www.ubid.com

Online auctions from company to seller. Items are grouped by type.

Some pop-up ads, so be careful.

Yahoo Auctions
auctions.yahoo.com

Like eBay, but not quite as busy. **SV**

About the Author

Gordon McComb is the author of the best-selling *Robot Builder's Bonanza*, *Robot Builder's Sourcebook*, and *Constructing Robot Bases*, all from Tab/McGraw-Hill. In addition to writing books, he operates a small manufacturing company dedicated to low-cost amateur robotics, **www.budgetrobotics.com** He can be reached at robots@robotoid.com

RoboBRiX Make Building Robots Easier

by William Benson and Wayne Gramlich

What's the hardest problem you face when building a mobile autonomous robot? We asked our HomeBrew Robotics Club members this question some time ago and the problem they cited most often was "real-time programming."

It turned out, to our surprise, that even though our San Jose, CA club draws its membership directly from residents in the heart of Silicon Valley, many of our members have little or no programming experience.

This was an unexpected revelation but it definitely explains why a club like ours — with an active membership of more than 30 members — has produced so few robots more complicated than a simple line follower.

Anyone who has built or has tried to build interesting features into their robot has come face-to-face with the realization that real-time programing complexity rises in a non-linear way with the addition of more complex robot functions. Consequently, it is no wonder that robot hobbyists, with little or no programming experience, often hit the limit of their programming ability with relatively simple robot designs. Our club's experience was a confimation of this fact. So, the question we asked ourselves was, "Can we find a way to get around this limitation?"

We knew that teaching members to become real-time programmers was not a feasible or time efficient solution. Therefore, we began looking for ways to effectively reduce and simplify the real-time code that a builder would have to write when building more complex robots.

In effect, we wanted to see if we could find a way to design robots where the code complexity, at worst, would rise linearly instead of non-linearly with the addition of new robot behaviors.

Wouldn't it be wonderful, for example, if a non-programmer roboticist could independently manage four servos and four Sharp IROD® (InfraRed Object Detection) sensors all at the same time without ever having to write a single critical timing loop or any device support code for either device type? And wouldn't it be even nicer yet, if he could have complete control of all of a device's features using uncomplicated one byte instructions?

These ideas were the genesis of a new way to envision robot building. We realized that any number of actuator and sensor devices could be easily incorporated into a robot creation with minimal code support if we could package them as individual modules that could essentially be "plugged in" to the robot as needed.

By simply incorporating a dedicated microprocessor and the necessary device circuitry on a single module or brick, we could manage all of the functions of any particular device using uncomplicated, one-byte commands sent to it by the user.

Using these actuator and sensor modules, or "function bricks" is easy. Each function brick links — by a four wire communications cable — to a master brick hub called a "Brain" (Figure 1). The Brain coordinates and controls the activities of each function brick in a master-to-slave relationship by issuing simple, one byte commands using a basic asynchronous serial communication protocol.

Figure 1.

A Brain brick (center) with two function bricks attached.

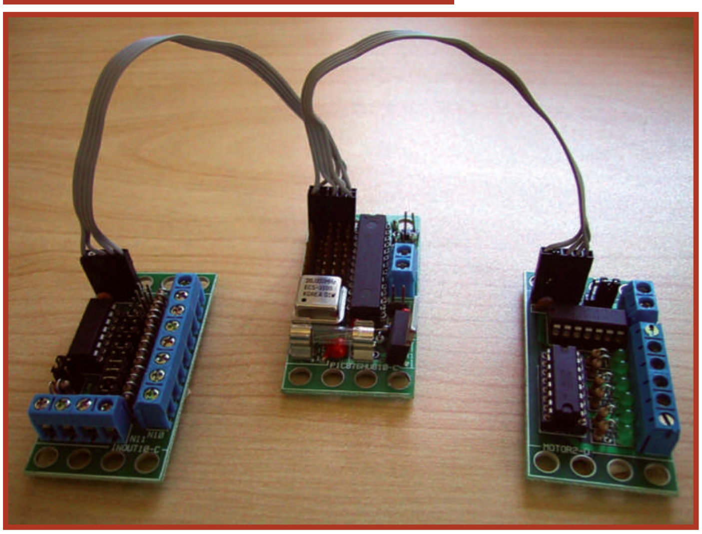
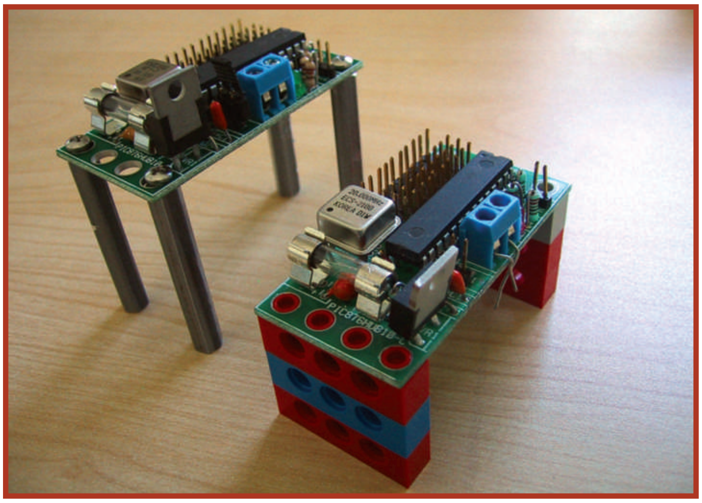


Figure 2.

Attaching RoboBRiX using standoffs as well as LEGO® bricks.



RoboBRiX Concept

Each function brick is pre-programmed with the real-time critical timing loops, special device software requirements, and other software complexities necessary for its dedicated function. This relieves the robot builder from the task of writing this very difficult code himself and from having to build much of the circuity to support the device.

In operation, the device code in the function bricks is invisible and inaccessable to the builder. But just as a driver doesn't need to know how a gasoline engine works in order to drive his car, the RoboBRiX user doesn't really need to know anything about how the function brick code is written to fully exploit its capabilities.

Accessing the many built-in capabilities of a function brick is done with a one or two byte command inserted in the top level program written by the builder and downloaded to the Brain brick. Each function brick has its own programming table that contains all of the unique commands needed to fully exploit the brick's capabilities. A sampling of some typical Servo4 brick commands is shown in Table 1.

RoboBRiX Specifications

An important objective in defining the RoboBRiX specifications was simplicity of design without degradation of performance. Besides subscribing to the "KISS" principle (Keep It Simple Stupid), we also wanted to motivate RoboBRiX users to ultimately "roll their own" and thus contribute to growing the inventory of RoboBRiX that could be shared with others.

Mechanical Specifications

The typical RoboBRiX module is built on a rectangular circuit board having a width of 1.25 inches and a length of 2.50 inches. The widths and lengths of non-standard RoboBRiX are always fabricated in multiples of 1.25 inches and 2.50 inches, respectively.

Along its width, each RoboBRiX board contains holes sized and spaced to fit LEGO® bricks, thus allowing LEGO users to implement their creations using RoboBRiX technology. Users can attach RoboBRiX with traditional standoffs or alternatively fit them onto LEGO bricks (Figure 2).

Electrical Specifications

A typical RoboBRiX system consists of a single hub brick connected to one or more function bricks via individual four wire cables (Figure 3). The cables provide +5 volt regulated DC power and ground from the hub to each function brick, along with two separate lines for sending and receiving data. The send and receive lines are TTL voltage compatible (i.e., 0-5 V).

The number of function bricks that can be connected to a hub brick is limited by the type of hub brick chosen. For example, the MicroBrain8 accomodates the Parallax Stamp and can control up to eight function bricks, while the PICBrain11 accomodates a PIC microprocessor and can control up to 11 function bricks. The number of function bricks that any hub brick can support is approximately equal to the total number of input/output ports available on the Brain microprocessor used divided by two.

Communication Specifications

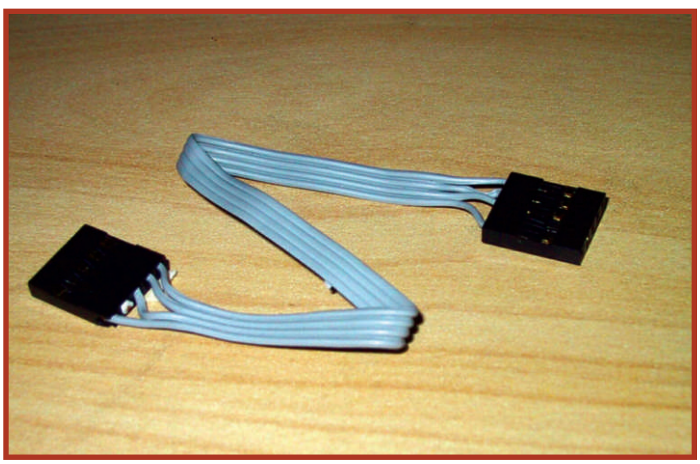
Asynchronous data transfer is done on a two line system where the lines are connected to specific input/output ports on the hub and function brick microprocessors.

Data is sent on one line and received on the other; the hub's transmit line is also the function brick's receive line and the hub's receive line is the function brick's transmit line.

Since function Bricks are attached to a specific socket on

Figure 3.

A typical four wire cable used to connect function bricks to a hub brick.



the hub, they do not need to have a uniqely assigned device address as they would if used, for example, in an I2C® network. However, offsetting this simplicity, socket technology has the disadvantage of limiting the number of function bricks that could otherwise be connected to any particular hub brick using unique device addresses. Since function bricks don't use uniquely assigned addresses, the hub socket number becomes the only address needed for serial communication. Hub/function brick communication is asynchronous; it proceeds first from the hub to the function brick and then from the function brick back to the hub using 2400 baud, 8N1 protocol (1 start bit, 8 data bits, no parity bit, and 1 stop bit). Communication between the hub and a function brick is always initiated by the hub; the function brick sends data to the hub only when the hub specifically instructs it to do so.

Implementation Example

For a typical example of how RoboBRiX can simplify programming, let's look at a commonly used way of providing mobility to a robot through the use of two servo motors, modified for continuous rotation, that use differential steering for direction control. We will control the servos using a Parallax Stamp microprocessor of the BS2 variety. The speed and direction of a servo is accomplished by sending a pulse of 0-1.5 µS duration no less frequently than every 20 mS. Without RoboBRiX technology, you will need to fit a 20 mS servo timing loop around all of the other BASIC Stamp code you write to support the other devices on your robot. The BASIC Stamp servo code might look something like this:

```
RunMotor:
    PULSOUT LMotor, LSpeed      'Pulse the left motor
    PULSOUT RMotor, RSpeed      'Pulse the right motor
' Wait here 20 mS ...
    GOTO RunMotor               'Pulse servos again
```

Now imagine that you want to add a sonar and a Sharp IROD sensor to you robot to work in combination as object detectors. Each of these devices also has its own unique and quite different timing requirement for operation. But the problem of managing three distinctly different timing loops is now becoming quickly non-trivial.

If you want to add any more devices to your robot that require periodic servicing to operate, you can see how the coding complexity can very rapidly become unmanagable.

So now let's look at how this process is simplified with the use of RoboBRiX. This time, we'll attach our servos to a Servo4 actuator brick and we'll plug our BASIC Stamp BS2 into a MicroBrain8 hub brick. A quick check of the Servo4 Programming Table tells us that we should use the Set High command to send speed instructions to the servos (i.e., RSpeed = 00hhhh00 and LSpeed = 00hhhh01). So our RoboBRiX code will look something like this:

```
RunMotor:
' Send speed instructions
        SEROUT Servo4_out, bs2_2400, [RSpeed]
        SEROUT Servo4_out, bs2_2400, [LSpeed]

'Attend to other matters
        GOTO DoSomethingElse
```

Conspicuously absent in the above code is any timing loop. That is because the Servo4 brick is taking care of this by itself so we don't have to do it in our code. For the same reason, we don't even have to send the Servo4 brick another speed command until we want to change the values last sent.

Adding the sonar and IROD bricks is trivial. And we can keep adding more bricks with devices that each have their own unique timing requirements without causing any significant increase in the complexity of our code.

Table 1.

Command	Send/Receive	Byte Value 7	6	5	4	3	2	1	0	Definition
Set High	Send	0	0	*h*	*h*	*h*	*h*	*s*	*s*	Set the high order 4 bits of servo ss to hhhh and set the remaining 4 low order bits to zero.
Set Low	Send	0	1	*l*	*l*	*l*	*l*	*s*	*s*	Set the low order 4 bits of servo ss position to llll.
Increment	Send	1	0	0	*i*	*i*	*i*	*s*	*s*	Add iii to the position of servo ss.
Decrement	Send	1	0	1	*d*	*d*	*d*	*s*	*s*	Subtract ddd from the position of servo ss.
Set Position/Enable	Send	1	1	0	0	0	*e*	*s*	*s*	Select servo ss and set its position to ppppppp and enable flag to e.
	Send	*p*	*p*	*p*	*p*	*p*	*p*	*p*	*p*	
Set Enable Flag	Send	1	1	0	0	1	*e*	*s*	*s*	Select servo ss and set its enable flag to e.

AVAILABLE RoboBRiX

MicroBrain8 — The BASIC Stamp®/OOPic-C® compatible brick used to send instructions and receive data with up to eight function bricks.

PICBrain11 — The Microchip PIC® compatible hub brick used to send instructions and receive data with up to 11 function bricks.

Servo4 — An actuator brick that provides independent control of up to four servo motors.

DualMotor1amp — An actuator brick that provides independent control of up to two one amp DC motors.

Digital8 — An actuator/sensor brick that has eight ports, each independently configurable as a digital input or an output to respectively read or send a bit of data.

IREdge4 — A sensor brick that controls up to four IR LED/Detector modules and is particularly well suited for line following and table edge detection.

IRProximity2 — A sensor brick that uses two modulated IR LEDs and detectors to achieve object detection at settable distances.

There are many more function bricks under development now with anticipated release within the next six months.

Purchase Information: You can now purchase RoboBRiX through The Robot Store's online catalog at **www.robotstore.com**

RoboBRiX website: **www.robobrix.com**
HomeBrew Robotics Club: **www.hbrobotics.org**

Copyright Information:

LEGO is a registered trademark of the LEGO Group
Microchip PIC is a registered trademark of Microchip, Inc.

OOPic-C is a registered trademark of Savage Innovations
BASIC Stamp is a registered trademark of the Parallax Corporation.

I2C is a registered trademark of Philips Semiconductors
RoboBRiX is a trademark of Mondo-tronics, Inc.

Summary

RoboBRiX are designed to simplify the task of real-time programming for the non-programmer robotic hobbyist so that they can design and build more complex robots.

But RoboBRiX offer other advantages as well. For example, most of the function bricks include the electronic circuitry necessary to support the sensor or actuator device it is designed to operate.

This relieves the user of having to build this circuitry for themselves, and eliminates any chance of making circuit design and construction errors that waste time on unnecessary troubleshooting.

Finally, RoboBRiX hubs are microprocessor independent. Any microprocessor chip can be used to build a hub brick as long as the simple RoboBRiX technical specifications are adhered to.

Next month, we will begin the first of a series of robot contstruction articles that utilize RoboBRiX technology. **SV**

GEER HEAD

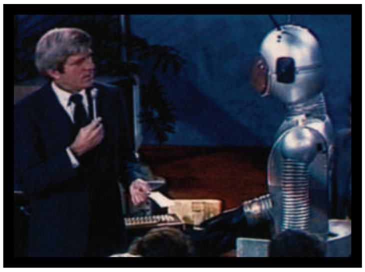
by David Geer

Modern robots from the past

Meet Arok

geercom@alltel.net

READ ME FIRST!



Test your knowledge of robots from the Previous Generation.

True or False?

Which of these amazing statements about our modern robots from the past are true, and which are not? Read the statements, decide whether they are true or false, and then read the article to get the real dish on these slightly dated dynamos!

1. Almost 30 years ago, free moving amateur robots could perform difficult, strenuous, and useful tasks with precision, despite their own heavy weight and girth. True or False?

2. Amateur robots existed a generation ago that could be programmed to travel on their own, complete useful tasks and talk, all without the use of modern computers. True or False?

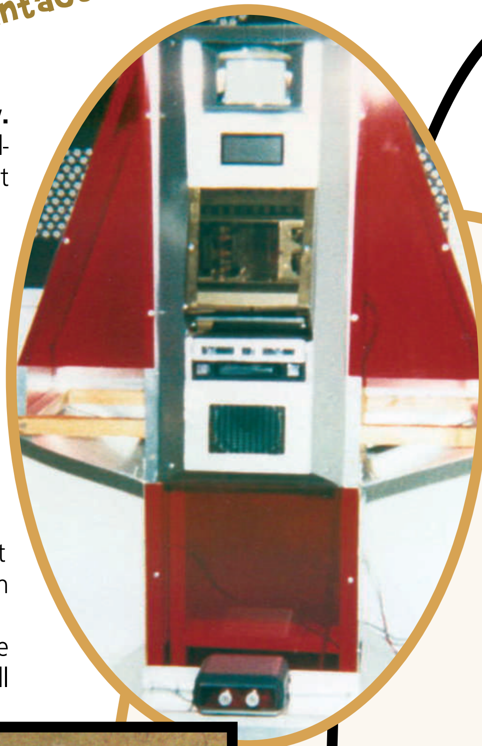
3. Amateur robots decades old could interact with people and respond based on human responses. True or False?

4. While the "blueprints" for one of the robots was nothing more than mental inspiration prompted by movie science fiction, another robot had no blueprints at all. True or False?

5. Finally, these strangely modern amateur robots could readily carry, set up, and operate construction tools to perform meaningful labor. True or False?

Think you guessed right on all counts? ***Read the article and see!***

Vintage against a Backdrop



The Unknowable ... and the Knowable

Who built the pyramids? How were they formed? Was it aliens? Was it earth-bound science evolved far beyond our own, now lost forever? Even with the discovery tools current technology is making available to us, we may never know.

What about strangely modern robots a generation old? Who made them? How did these inventors imbue their master works with advanced functions and mobility? This we know!

Vintage

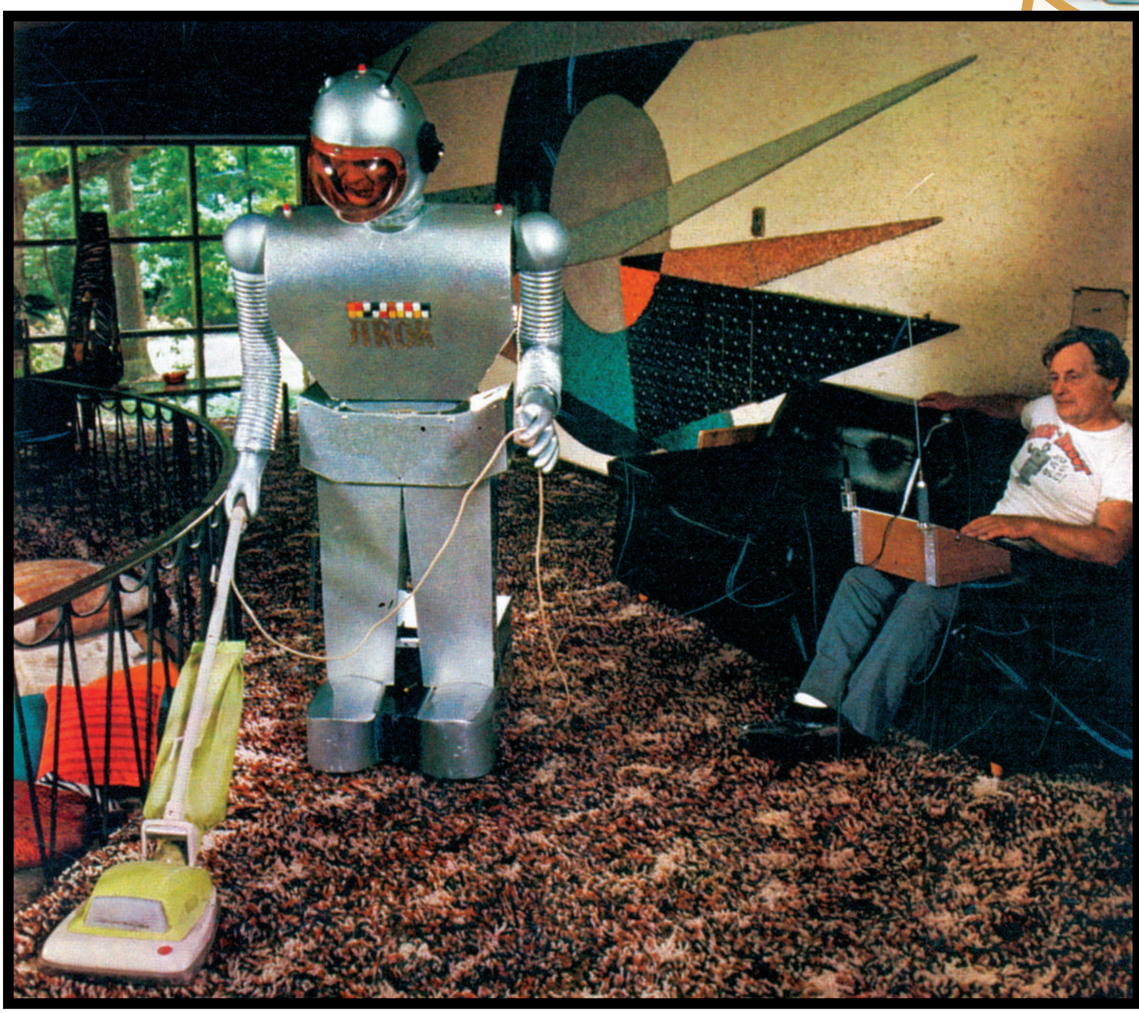
Anthony Ellis, Conceptioneer (inventor/product developer, **www.conceptioneering.co.uk**) is the trail-blazing roboticist behind our first modern robot from the past.

If you're new to robotics, or haven't kept up with news from across the pond, you probably haven't heard of this "vintage" robot. Meet Anthony Ellis' 23-year-old creation, appropriately named Vintage.

Vintage came to life in 1981, in Ellis' home in Mitcham, Surrey, England.

The robot's body was aluminum sheeting over a wooden subframe. It stood about five feet tall, bigger than most state-of-the-art robots.

Though Ellis couldn't confirm the exact price tag, Vintage cost a small



fortune in British pounds to piece together.

The Concept

Vintage was loosely based on the Droids in the movie "Silent Running" (1972). As with many amateur robots (and not unlike Frankenstein's monster), Vintage was one-of-a-kind, a prototype with no production model. Ellis had to acquire many new skills to complete him.

Programming

Vintage learned by doing. Fully programmable, he was remote controlled (based on tone decoding). Tones were fed to Vintage, which triggered his responses.

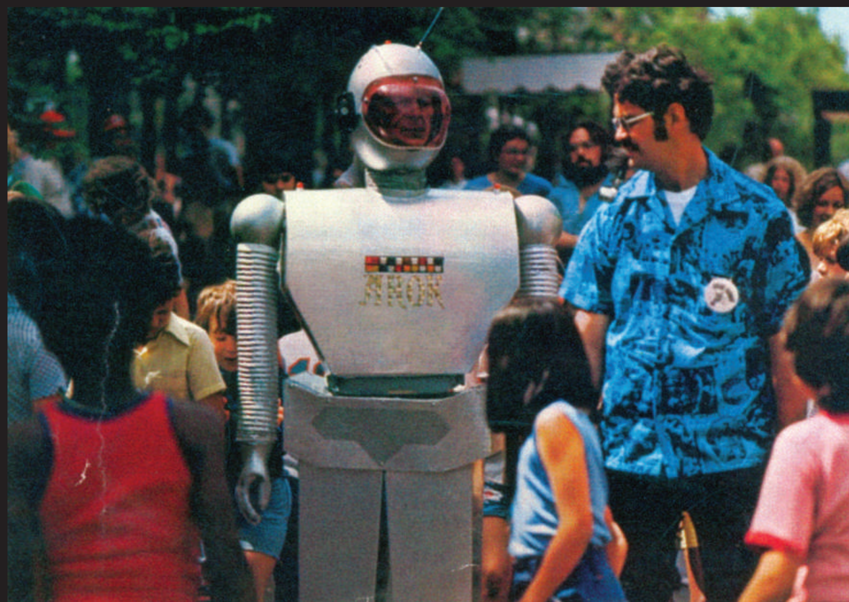
The tones were simultaneously recorded to cassette. The tape was played back from a player in the robot's belly (which was taken from a car stereo). Vintage followed commands from the tape, as well as manually.

Eventually, tone sequences and voice were both recorded to tape (by splitting stereo channels). The robot could then be programmed to speak at times that coincided with specific movements.

Vintage was capable of a variety of activities, using each of his moving parts, including his arms and claws.

These arms and claws emerged from the front casing, just as they did on the Silent Running Droids.

The arm mechanisms were worm driven, moving the mechanical appendages from a vertical position, parallel with the body, to a horizontal position, away from the body.



Vintage could carry a tray and drink glass to a designated position where a participant would be waiting, and say, "Your drink, Sir."

The tape would stop until the drink left the tray, then the robot would move back to its starting position.

"Warning, Warning! Danger, Danger!"

On one occasion, the tape player malfunctioned. Vintage careened uncontrollably around the room, in wild, random motions — a machine out of control!

He toppled furniture and completely demolished the room. Because the ultrasonics were down so that Ellis could work on the robot, it couldn't evade collisions.

There was no override switch and, due to the malfunction, the radio frequency (RF) link wasn't available to shut the robot down.

Ellis had to chase him until he could remove the rear access panel and pull a battery lead.

Arok

Twenty-eight years ago, inventor and engineer, Ben Skora, brought a 6'8" robotic masterpiece named Arok to life. At the time, Arok was advertised as the most humanoid robot. Instilling human movement into Arok was the most challenging part of his construction. Arok had full range of motion in his wrists, shoulders, elbows, and waist. He could also speak, and glide across the floor.

Materials and Construction

Arok was made of an all aluminum body over an aluminum frame, with a steel base to maintain center of gravity. Two huge marine batteries provided Arok's power, and added additional ballast to the base.

When Arok was built, you couldn't get ready-made mini-motors and other robot parts. Arok ran mostly on motors taken from electric car windows. These motors were rebuilt to have different

gear ratios. Arok was made from scratch, by trial and error, without plans or blueprints.

First, Skora made the robot's base and drive unit. He tested it out by riding it around in his driveway, sitting on a milk case. Next, he attached the legs and waist.

Skora wrestled with decisions about his robot's construction. Initially, Arok's waist could only turn.

One night, Skora made up his mind that the robot had to both turn and bend at the waist. He took Arok all apart again and worked on him until he could do both.

This was an advanced feature for a robot first built in the 70s. All in all, the robot's construction took almost three years.

Arok was capable of wildly unpredictable turns and movements. Two wheels in back kept him from tipping over. When he hit those wheels, he bounced right back into position.

Arok 's elbows and shoulders were built and rebuilt until Skora was satisfied with their flexibility. Arok's shoulders were a coax arrangement — one motor went *through* the shoulder, and there was a pivot where the shoulder went. A cable then ran through the shoulder and down to the elbow mechanism. Another motor raised and lowers the shoulder and the elbows were made of jack screws.

Arok's face was a rubber mask. When Ben Skora spoke into the console, his voice came out of the robot's mouth.

An Estimated Bill for Arok

The labor for Arok, calculated for the three years it took Skora to build him, would have run up to $750,000.00, including machine work and welding.

Operation

Arok was remote controlled and tape programmable. RF signals sent out tones to communicate commands for the robot to obey.

The commands were recorded to tape inside of Arok. When the tape was then played back, the robot performed the same behaviors automatically, essentially responding to the same commands.

Skora utilized a private line (PL) as a safety precaution. When Arok's transmitter was active, a continuous low-frequency signal was sent to Arok. If Arok didn't hear that signal (like if the transmitter went out), he stopped automatically.

Though the robot could do many things by following programs on tape, not many of those programs could be run in large crowds. Children got too close to the robot to guarantee safety when it was controlled by tape.

Some of Arok's Easier Jobs

Arok did live promotions and product demonstrations. Remember, it was 28 years ago when audiences were first amazed by Arok's ability to perform the following, very human, activities.

One of Arok's talents included lifting and carrying people who weighed up to 110 lbs.; quite an accomplishment for a robot that itself only weighed about 285 lbs.

Arok could pour drinks with full wrist action, walk the dog and vacuum the floor. Arok participated in ribbon cutting ceremonies, slicing the ribbon himself with a laser. (Wow! - Editor Dan)

Arok Turned Heads

Skora would run Arok by remote for part of the show, recording commands to tape. Frequently from show to show, a random married couple would come walking by (and the wife would wonder how the robot could do such amazing things).

The husband would respond "Oh yeah, that's by remote, he's around here somewhere, oh, there he is in the corner over there" (speaking of Skora, who was visibly controlling the robot from the console).

Then Skora would start the tape playback and put down the console.

The robot would then follow Skora around. The man in the audience would become bewildered, having no explanation for how the robot was working apart from the remote.

Arok's Sense of Humor

Skora made Arok, and Arok returned the favor — by making monkeys of his audience. Arok had a built-in Polaroid camera and offered to take pictures of audience members.

The film was usually reloaded with pictures of monkeys.

The robot would verbally instruct people to pose for a picture. Arok would take the picture and when it was pulled from the camera there would be the monkey.

Fascinating Feats

There were 10 different controls available to Skora from the remote console. With these and Arok's unique construction, the robot could perform several strenuous, complicated and useful activities.

One of the most impressive was Arok's demonstration using a company's roto-hammer product (something in the family of a jackhammer) on a concrete block. Arok carried the cement block and the roto-hammer on stage, set the block down and started drilling holes into it. In another demonstration, Arok used a screw gun to put up drywall. He held the drywall in place and shot the screws into position.

Epilogue

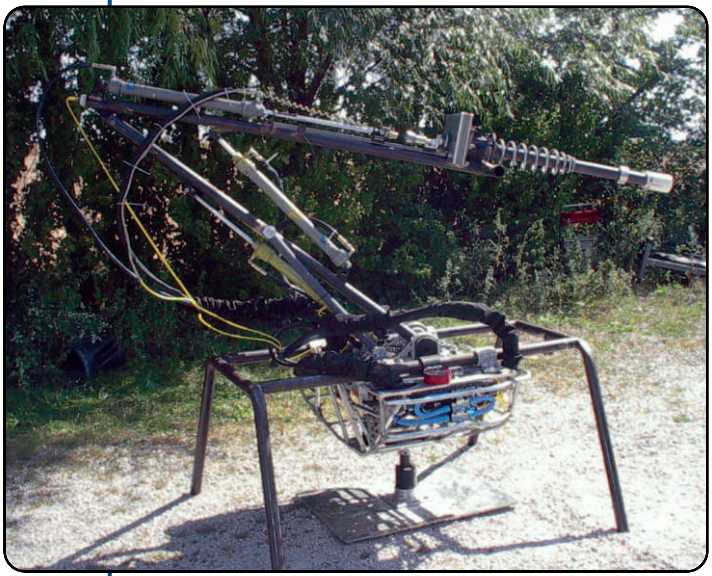
Did you read the True or False section first? If so, you know that we toyed with you, didn't we? Yes, all the statements about these modern robots from the past were true.

Pretty impressive, isn't it? Are you the maker of a futuristic robot? Don't retire him too early. You never know when your surprisingly modern robot will be called upon to return to the limelight ... perhaps in the pages of *SERVO*. **SV**

MENAGERIE

Russell's Paradigm

Ken Russell, Maroa, IL



This is a 514 pound, radio controlled, walking combat robot. It is powered by a 32cc internal combustion engine which, in turn, powers a hydraulic pump.

It "walks" by extending the center foot down, lifting the outside legs off the ground, sliding the outside legs forward, and then setting them back down. The center foot then retracts, and the body slides forward. The whole robot turns by extending the center foot, and rotating upon it.

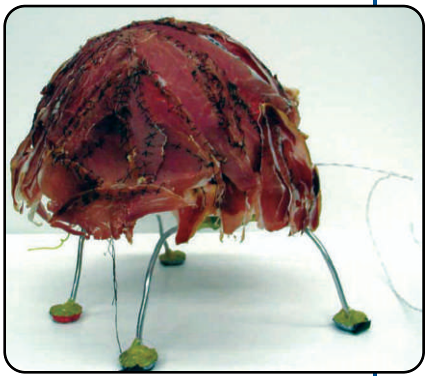
The weapon is a harpoon on the end of an arm which has three degrees of motion. Its combat debut was at Mechwars, in October 2003.

Patty

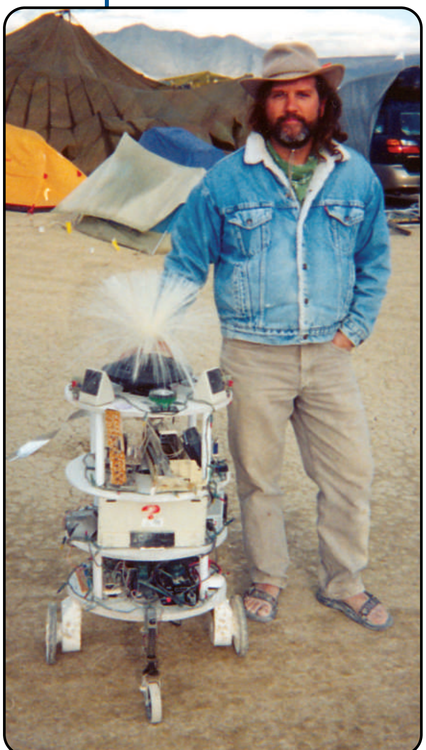
Dan Mikesell, New York, NY

Walking meat on a leash! Yes, it's Patty! This meat-covered robot was made for an art show in New York. She scampers along the floor getting lots of attention wherever she goes! Her endearing lopsided gait warms even the coldest of hearts though she does need some refrigeration.

www.meatbot.com



Send us a high-res picture of your robot with a few descriptive sentences and we'll make you famous. Well, mostly.
menagerie@servomagazine.com

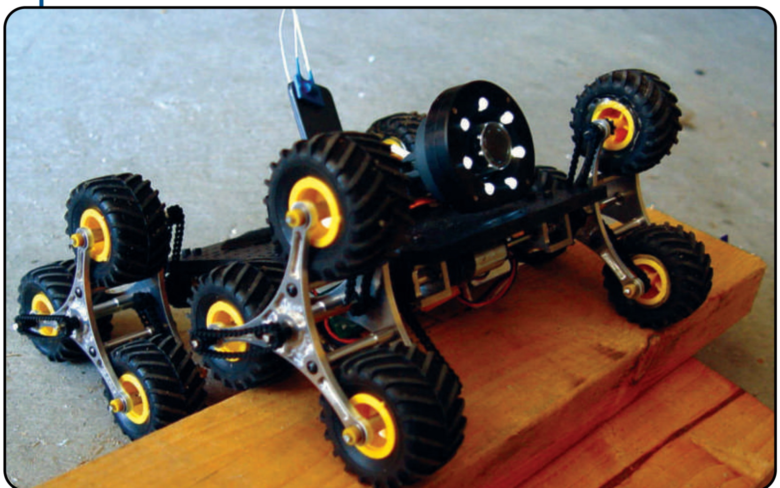


Springy Thingy

Camp Peavy, Palo Alto, CA

This is my Burning Man "Artbot," and my yearly goal is to simply leave the event with her still functioning.

Currently, she is remote controlled with an intercom system and Quickcam. But in autonomous mode, she is Stamp-based and follows a beacon until she can grasp it. The onboard 900 MHz PC is used to monitor sensors, play MP3s, and take digital photos. This was Spring's fifth successful "burn."



Camera Bot

Eric Stoliker, Burbank, CA

Inspired by "Robot Expedition" on Discovery Channel, my R/C robot mounts a 120-degree FOV camera surrounded by seven ultrabright LEDs on a servo-controlled tilt rig. It gives me a rat's eye view, whether I'm driving under the house or in the attic.

The unique tri-wheel design lets me deal with uneven terrain like the front lawn or the stairs.

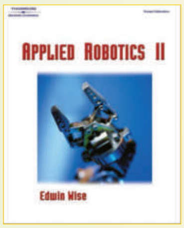
The SERVO Bookstore

Mind Candy For Today's Roboticist

Robot Companions
by E. Oliver Severin

With *Robot Companions*, you'll learn how to build your own robot for purposes such as companionship, supervision of the elderly, tutoring the young, doing household chores, and much more. The book delves into essential enabling technologies such as mobility, voice, communications, touch, sight, and smell response so you'll understand the mechanics behind form, function, and personality. **$24.95**

Applied Robotics II
by Edwin Wise

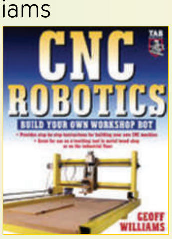


Instructive illustrations, schematics, part numbers and sources are also provided, making this book a "must" for advanced builders with a keen interest in moving from simple reflexes to autonomous, AI-based robots. Create larger and more useful mobile robots! Ideal for serious hobbyists, *Applied Robotics II* begins by discussing PMDC motor operation and criteria for selecting drive, arm, hand and neck motors. **$41.95**

Robot Mechanisms and Mechanical Devices Illustrated
by Paul Sandin

Both hobbyists and professionals will treasure this unique and distinctive sourcebook — the most thorough and thoroughly explained — compendium of robot mechanisms and devices ever assembled. Written and illustrated specifically for people fascinated with mobile robots, *Robot Mechanisms and Mechanical Devices Illustrated* offers a one-stop source for everything needed for the mechanical design of state-of-the-art mobile 'bots. **$39.95**

CNC Robotics
by Geoff Williams

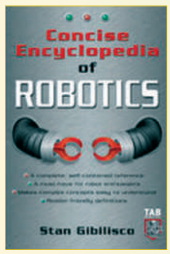


Now for the first time you can get complete directions for building a CNC workshop bot for a total cost of around $1,500.00! *CNC Robotics* gives you step-by-step, illustrated directions for designing, constructing, and testing a fully functional CNC robot that saves you 80 percent of the price of an off-the-shelf bot —and that can be customized to suit your purposes exactly, because you designed it. **$34.95**

Robot Builder's Bonanza
by Gordon McComb

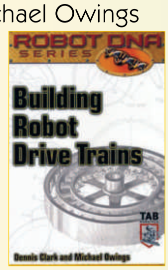
Robot Builder's Bonanza is a major revision of the bestselling bible of amateur robotics building — packed with the latest in servo motor technology, microcontrolled robots, remote control, Lego Mindstorms Kits, and other commercial kits. It gives electronics hobbyists fully illustrated plans for 11 complete Robots, as well as all-new coverage of Robotix-based Robots, Lego Technic-based Robots, Functionoids with Lego Mindstorms, and Location and Motorized Systems with Servo Motors. **$24.95**

Concise Encyclopedia of Robotics
by Stan Gibilisco



This handy collection of straightforward, to-the-point definitions is exactly what robotics and artificial intelligence hobbyists need to get and stay up to speed with all new terms that have recently emerged in robotics and artificial intelligence.
Written by an award-winning electronics author, the *Concise Encyclopedia of Robotics* delivers 400 up-to-date, easy-to-read definitions that make even complex concepts understandable. Over 150 illustrations make the information accessible at a glance and extensive cross-referencing and a comprehensive bibliography facilitate further research. **$19.95**

Building Robot Drive Trains
by Dennis Clark / Michael Owings



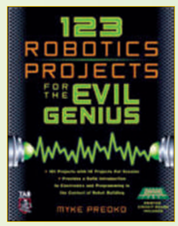
This essential title in McGraw-Hill's *Robot DNA Series* is just what robotics hobbyists need to build an effective drive train using inexpensive, off-the-shelf parts. Leaving heavy-duty "tech speak" behind, the authors focus on the actual concepts and applications necessary to build — and understand — these critical force-conveying systems. If you're hooked on amateur robotics and want a clear, straightforward guide to the nuts-and-bolts of drive trains, this is the way to go. **$24.95**

We accept VISA, MC, AMEX, DISCOVER
Prices do not include shipping and may be subject to change.

Robot Builder's Sourcebook
by Gordon McComb

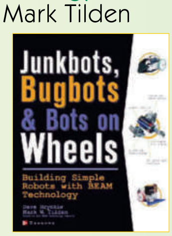
Fascinated by the world of robotics but don't know how to tap into the incredible amount of information available on the subject? Clueless as to locating specific information on robotics? Want the names, addresses, phone numbers, and websites of companies that can supply the exact part, plan, kit, building material, programming language, operating system, computer system, or publication you've been searching for? Turn to *Robot Builder's Sourcebook* — a unique clearinghouse of information that will open 2,500+ new doors and spark almost as many new ideas. **$24.95**

123 Robotics Projects for the Evil Genius
by Myke Predko



If you enjoy tinkering in your workshop and have a fascination for robotics, you'll have hours of fun working through the 123 experiments found in this innovative project book. More than just an enjoyable way to spend time, these exciting experiments also provide a solid grounding in robotics, electronics, and programming. Each experiment builds on the skills acquired in those before it so you develop a hands-on, nuts-and-bolts understanding of robotics – from the ground up. **$25.00**

JunkBots, Bugbots, and Bots on Wheels: Building Simple Robots With BEAM Technology
by David Hrynkiw / Mark Tilden



Ever wonder what to do with those discarded items in your junk drawer? Now you can use electronic parts from old Walkmans, spare remote controls, even paper clips to build your very own autonomous robots and gizmos. Get step-by-step instructions from the Junkbot masters for creating simple and fun self-guiding robots safely and easily using common and not-so-common objects from around the house. Using BEAM technology, ordinary tools, salvaged electronic bits, and the occasional dead toy, construct a solar-powered obstacle-avoiding device, a mini-sumo-wrestling robot, a motorized walking robot bug, and more. Grab your screwdriver and join the robot-building revolution! **$24.99**

To order call 1-800-783-4624 or go to our website at www.servomagazine.com

Combat Robot Weapons
by Chris Hannold

Packed with informative illustrations, *Combat Robot Weapons* also expands on fighting strategies for each weapon type to further solidify your understanding. The enclosed CD-ROM contains spinner weapon plans, robot combat videos, software, and more that will help you turn your robot into a battle-ready metal warrior. **$24.95**

Robot Programming
by Joe Jones / Daniel Roth

Using an intuitive method, *Robot Programming* deconstructs robot control into simple and distinct behaviors that are easy to program and debug for inexpensive microcontrollers with little memory. Once you've mastered programming your online bot, you can easily adapt your programs for use in physical robots. **$29.95**

The Ultimate Palm Robot
by Kevin Mukhar / Dave Johnson

Now, anyone curious about robotics can inexpensively build and enjoy their very own robot using any Palm handheld for the brains. Originally developed by Carnegie Mellon University robotics department graduate students, this prototype has enjoyed a cult following among enthusiasts. Using software provided by the authors and this step-by-step guide, you can build and operate your own version of the same robot. Recycle your old handheld, or get someone elses for peanuts on eBay or at a flea market. Learn about parts, software, programming, games, robot resources, and much more from this exciting one-stop guide to Palm robots. **$29.99**

Check out our online bookstore at www.servomagazine.com for a complete listing of all the books that are available.

Robots, Androids, and Animatrons: Second Edition
by John Iovine

There's never been a better time to explore the world of the nearly human. You get everything you need to create 12 exciting robotic projects using off-the-shelf products and workshop-built devices, including a complete parts list. Also ideal for anyone interested in electronic and motion control, this cult classic gives you the building blocks you need to go practically anywhere in robotics. **$19.95**

PDA Robotics
by Doug Williams

The virtual chasm between PDAs and robots has been spanned, with McGraw-Hill's *PDA Robotics: Using Your Personal Digital Assistant to Control Your Robot*, an easy-to-read guide to integrating these two pieces of technology into a single, remote-controlled powerhouse. **$24.95**

ArtBots 2003

The Robot Talent Show

by Karl Williams

*I had the pleasure of attending the second annual Artbots Robot Talent Show held in New York City (**www.artbots.org**). The Robot Talent Show took place at the EYEBEAM Gallery (**www.eyebeam.org**) on July 12-13, 2003 as a part of EYEBEAM's summer robotics festival called ROBOT. The Artbots show featured the work of 22 artists and groups from six countries. It was a great success with over 2,000 visitors, as well as local, national, and international press coverage in print, television, and on the web. EYEBEAM's goal is to "engage a cultural dialog at the intersection of the arts and sciences and to forge an understanding of their relatedness."*

You might be wondering, what is an Artbot? An Artbot is a robot that either creates art, or a robot that is a work of art (which goes without saying for all robots). Since there are no clear definitions of what is considered art or what exactly a robot is, it gets interesting when the two are mixed.

The gallery is a converted brick warehouse with track lighting and air conditioning, located in the Chelsea district. The shows curators, Philip Galanter, Douglas Repetto, and Jenny Lee, along with the artists were on hand to talk about the show and the exhibits.

FIGURE 1.
Philip Galanter — one of Artbots' Curators.

The show was well organized and I had a lot of fun talking to the artists/roboticists and taking lots of pictures. I'll definitely be back next year!

A short description of each exhibit along with a photograph is outlined below.

FIGURE 2.
Happy Feet: Stephen Turbek (Brooklyn, NY)

Happy Feet is an installation of five pairs of elegant footwear. Each shoe is mechanically articulated, enabling it to tap. The shoes are then free to dance, to create chorus line patterns, to interact with the audience.

SEEMEN build machines and robots that a live audience can operate. This is an art that is a mix of robots, machines, sculpture, computers, science, invention, audience interaction, and storytelling. They are interested in giving audiences a real life experience, not a passive virtual one, to make the volunteers cyborgs. Humans themselves become part of "the Machine" in an attempt to become one organism.

FIGURE 3.
Monkey On Your Back: Kal Spelletich/SEEMEN (San Francisco, CA)

"An Artbot is a robot that either creates art, or a robot that is a work of art."

LEMUR: League of Electronic Musical Urban Robots (Brooklyn, NY)

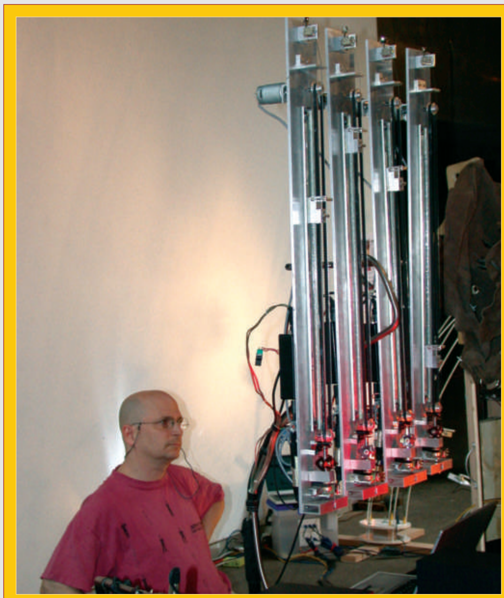


FIGURE 4.
GuitarBot: Eric Singer, Kevin Larke, David Bianciardi

FIGURE 5.
!rBot ("chik-r-bot"): Jeff Feddersen, Milena Iossifova, Michelle Cherian, Brendan J. FitzGerald, Ahmi Wolf

LEMUR presented four musical robots. GuitarBot, an electric stringed instrument, is comprised of four independently controllable stringed units which can pick and slide extremely rapidly. It is designed to extend — not simply duplicate — the capabilities of a human guitarist. !rBot (pronounced "chick-r-bot") fuses traditional musical instruments with mechanical design. Inspired by the human mouth, its malleable cavity opens to expose and play a Peruvian goat-hoof rattle. TibetBot is a robotically controlled percussive instrument that creates atonal rhythms and tonal droning soundscapes. It is designed around three Tibetan singing bowls, which are struck by six robotic arms, producing a wide range of timbers. ShivaBot is a four-armed, six-foot tall drumming robot, based on the Indian god Shiva and designed around a traditional Indian lap drum. It also accommodates a variety of drums and other percussion instruments, such as bells, chimes, and cymbals.

FIGURE 6.
ShivaBot: Kyle Lapidus, Jonathan Huggins, Clay Lacefield

FIGURE 7.
TibetBot: Chad Redmon, Kate Chapman

FIGURE 8.

Fotron2000: Daniel Paluska, Jessica Banks, jackbackrack (Cambridge, MA)

The Fotron2000 is tomorrow's answer to today's mall photo booth. At its heart is a robotic sketch artist whose medium is LED light and whose canvas is long exposed Polaroid film. The robot draws quickly, rendering a line drawing of its subject, which he or she gets to keep.

FIGURE 10.

50 drones: David Bowen (Minneapolis, MN)

This Artbot is made up of 50 small circular wheeled robots all tethered to a base hanging from the ceiling.

> "... engage a cultural dialog at the intersection of the arts and sciences, and forge an understanding of their relatedness."

ForestBot is the newest LEMUR robot and is the evolutionary offspring of !rBot. ForestBot is not a singular robot but rather a robotic installation. It consists of 25 ten-foot stalks that gently arc up from bases on the ground. Each stalk has an egg-shaped rattle mounted at the free end and a small aluminum armature affixed near the base. The armature at the base supports a motor with an asymmetrical counterweight which, when spun by the motor, vibrates the entire stalk, and thus causes the rattle to sound. The stalks are in clusters, with five sharing a single base. The robot's five bases can be arranged such that a person interacting with it can stand entirely surrounded by the stalks, with the rattles dispersed in the air just above head level.

Visit the LEMUR website (**http://lemurbots.org/**) to learn more about their work, as well as watch videos and listen to audio of their machines in action.

FIGURE 9.

ForestBot: Jeff Feddersen, Milena Iossifova

The Tickle Salon is a robotic installation based on the concept of automated stroking. The massaging machine is designed to stroke with indefatigable attention and subtleness, uniting the artists' interests in "meta creativity, biology and artificial intelligence and, of course, the pleasure of being stroked." The installation consists roughly of three parts: a robot attached to the ceiling, a bed standing on the floor, and a human being lying on the bed.

The robot uses a suspended probe to grope and feel the surface underneath. Gradually, the robot develops an image of the body that is lying on the bed. Using its imagination, the robot is able to execute sensitive movements over the skin surface. It aims to be smart, smooth, and unpredictable. In the room, a human being is lying on a bed. In between the bed and the ceiling, a suspended feeler is attached to four threads. The feeler can be moved around freely by varying the length of the four threads. This is achieved by computer controlled stepper motors that wind and unwind the treads. The feeler can reach any position in three-dimensional space, in between the bed and the ceiling. At each moment in time, the feeler knows exactly where it is.

FIGURE 11.
Tickle Salon: Erwin Driessens, Maria Verstappen (Holland)

The Semi Living Artist is a geographically detached, bio-cybernetic project exploring aspects of creativity and artistry in the age of biological technologies and the future possibilities of creating semi living entities.

FIGURE 12.
MEART — "The semi living artist" : SymbioticA Research Group in collaboration with The Steve Potter Lab (Douglas Bakkum, Guy Ben-Ary, Dr. Stuart Bunt, Oron Catts, Phil Gamblen, Steve M. Potter, Ian Sweetman, Ionat Zurr) (Western Australia/Atlanta, GA)

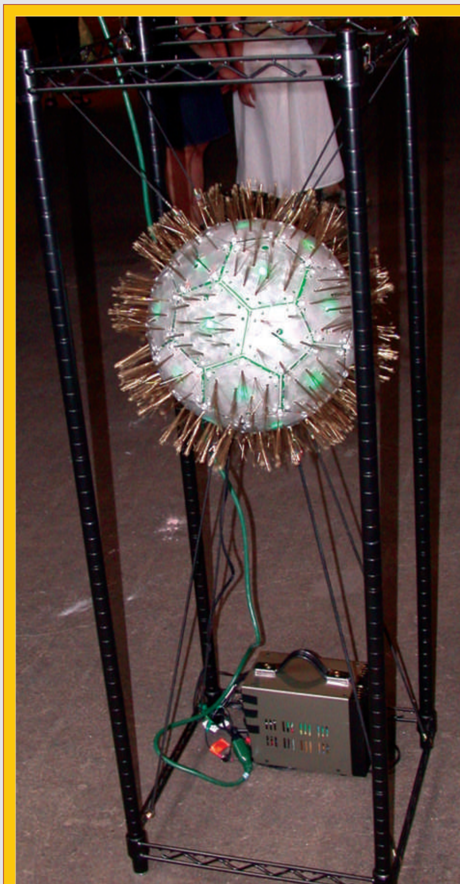


FIGURE 13.

Tribblation: Josh Lifton, Michael Broxton, Joseph Paradiso (Cambridge, MA)

This work is motivated by the prospect of complementing traditional actuation-centered robotics with sensory capabilities similar to those of a biological skin. This is the first public appearance of Tribble (The Robotic Interactive Ball-Based Living Entity). Independent sensing patches comprising Tribble's outer surface communicate with neighboring patches to form a distributed sensor network of electronic sensate skin, complete with instrumented whiskers, pressure sensors, microphones, temperature sensors, and light sensors.

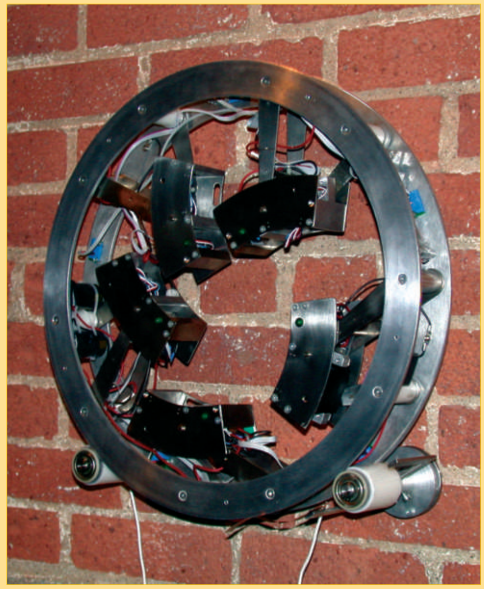
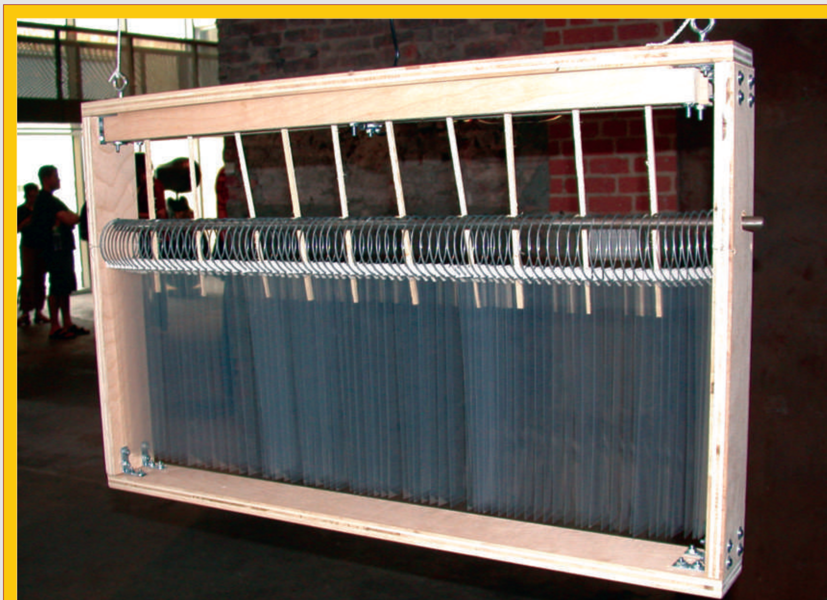


FIGURE 14.

micro.adam & micro.eva : Julius Popp (Berlin, Germany)

micro.adam and micro.eva are two simple robots who discover their own bodies and develop body-consciousness on a minimal basis. Like Adam and Eve in paradise became conscious and had to leave the garden, now micro.adam and micro.eva, two machines, are about to cross that same border.



In the physical world, transmutation is never perfect. Slowscan Soundwave is one in a series of pieces that attempt to create simple physical manifestations of complex physical, biological, and social phenomena.

FIGURE 15.

Slowscan Soundwave: Douglas Irving Repetto (New York, NY)

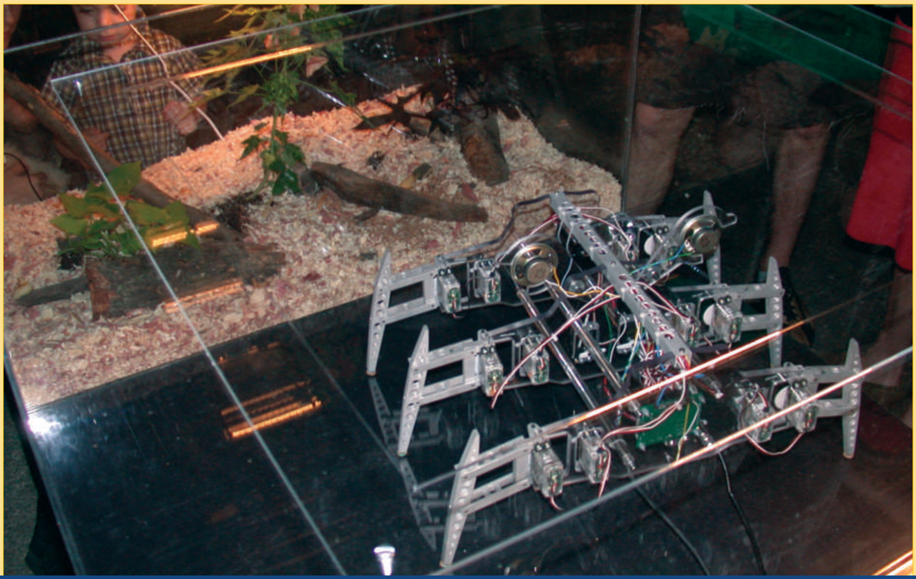


FIGURE 16.

Small work for robot and insects : Host Productions (Liverpool, UK)

Small work for robot and insects stages an attempt to establish communication between a colony of insects (one of the most ancient of all life forms) and a robot (rapidly becoming one of the most advanced). The robot has a neural network brain with which it listens to, analyses and generates responses to the calls of insects with sequences of motion, lights and sounds.

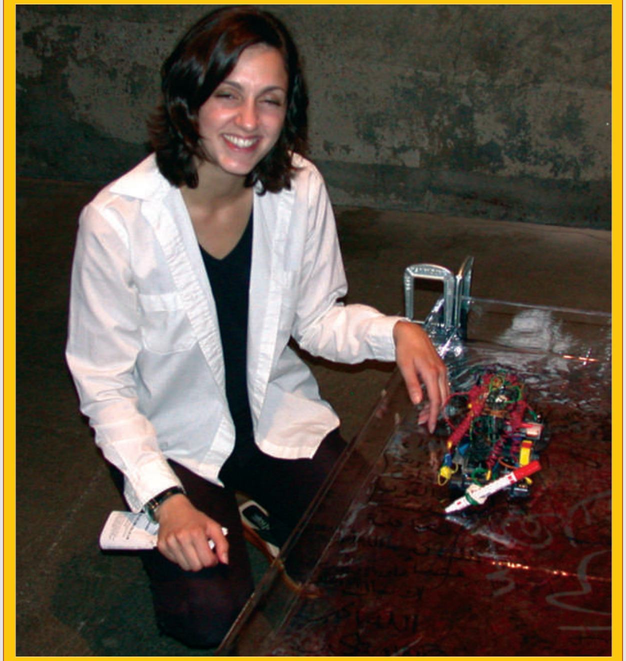


FIGURE 17.

re-capacitance: Leesa and Nicole Abahuni (Farmingdale, NY)

This exhibit consists of a graffiti-drawing robot that interacts with the audience by reacting to graffiti that the humans have drawn.

"... the work of 22 artists and groups from six countries."

Drawing Machine 3.1415926 v.2 explores the possibility of creating machinery or systems that create art objects on their own. In this case, the machine has been designed to listen to its environment (using a series of microphones installed around the gallery) as a method for generating the drawings.

FIGURE 18.

Drawing Machine 3.1415926: Fernando Orellana (Columbus, OH)

FIGURE 19.

Automated Architecture Robot: Ira Spool, Anna Tsypin (Brooklyn, MA)

This robot sculpts a block of ice into a house or building using water.

Lev, a machine for playing the theremin, is named after Lev Termen or Leon Theremin. Theremin was a Russian scientist who invented one of the first electronic musical instruments. The theremin is played without touching. SV

FIGURE 20.

Lev: Ranjit Bhatnagar (Brooklyn, NY)

ArtBots Sponsors

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The Columbia University Computer Music Center
(**http://music.columbia.edu/cmc**)

Hosting Organization: EYEBEAM
(**http://eyebeam.org**)

Other Sponsors:
Pratt Institute (**http://pratt.edu**)
The NYU Arts Technology Group
(**www.nyu.edu/its/atg/**)

Author Bio

Karl P. Williams is an independent robotics researcher, software developer, and writer. He is the author of two robotics books titled *"Insectronics: Build your own six legged walking robot"* and *"Amphibionics: Build your own biologically inspired robots"* published by McGraw-Hill. He hosts a robotics website (**http://home.golden.net/~kpwillia**) and can be contacted through **www.thinkbotics.com**

EVENTS CALENDAR

Send updates, new listings, corrections, complaints, and suggestions to: **steve@ncc.com** or **FAX 972-404-0269**

Welcome to 2004. What sort of robot competitions are in store for us this new year? Lots of everything. January is always a little slow but we're closing in on April, which is packed with more robot competitions than any other month of the year. This year is no exception with 10 confirmed events already. Expect more to be added during the coming weeks.

I've had some interesting discussions recently on the future of robot competitions. There are more competitions now than at any other time in the 10 years I've maintained the Robot Competition FAQ. However, numerous readers have provided anecdotal evidence of a decline in public attendence at several of the major events over the last year.

Some have attributed this decline to misperceptions among the public as to what robot competitions are all about; misperceptions created by the mass marketed "corporate" TV events like the radio-controlled vehicle battle shows Robot Wars and BattleBots.

Others have suggested that the problem is simply that of too many events. Some local robot clubs have gone from holding one or two major events per year to as many as one a month.

And one plausible explanation is simply that it has more to do with the current economy than with any long-term trend in the robotic world.

A final theory I've heard proposed is that we're very nearly to a time when robots are commonplace and this is leading to a natural shift in the nature of robot clubs and events.

Before PCs were common, there were homebrew computer clubs. Such clubs are rare now but Computer User Groups and SIGs have proliferated. Will homebrew robot clubs eventually be replaced by robot user groups? And how will this affect the future of robot contests?

If you have any thoughts on these theories or perhaps a theory of your own, write or Email us at SERVO Magazine.

— R. Steven Rainwater

For last minute updates and changes, you can always find the most recent version of the complete Robot Competition FAQ at Robots.net:
http://robots.net/rcfaq.html

January 2004

17 **MURC**
Lakewood, CO
Radio-controlled vehicle combat brought to you by the Mid US Robotics Club
www.murconline.com/

24-26 **Yantriki TECHFEST**
TECHFEST 2004, IIT, Bombay, INDIA
This is a huge technical festival involving over 15,000 students from 750 colleges across India. There are a lot of other technical contests in addition to the robotics events.
www.techfest.org

24-26 **CLIFFHANGER**
TECHFEST 2004, IIT, Bombay, INDIA
In addition to the Yantriki contest, TECHFEST is also hosting a new event intended to be an international competition for rope-climbing robots.
www.techfest.org/cliffhanger/

February 2004

22-26 **APEC Micromouse Contest**
The Disneyland Hotel, Anaheim, CA
This will be the 18th annual event for one of the best-known micromouse competitions in the United States. Expect to see some very advanced (and fast!) micromouse robots.
www.apec-conf.org/2004/APEC04_Home_Page.html

March 2004

12-13 **AMD Jerry Sanders Creative Design Contest**
University of Illinois at Urbana-Champaign, IL
This year robots will play Tetris by forming a completed puzzle out of nine standard Tetris shapes on a 36' x 36' playing field.
http://dc.cen.uiuc.edu/

Courtesy of ROBOTS.NET

13 **DARPA Grand Challenge**
Los Angeles, CA
An autonomous LA to Vegas cross-country, off-road, race for a one million dollar prize. Not your average robot contest — especially if you didn't make that cut of 19!
www.darpa.mil/grandchallenge/

13-14 **Manitoba Robot Games**
Manitoba Museum of Man and Nature, Winnipeg, Manitoba, CANADA
This interesting assortment of robot events includes mini sumo, Japanese sumo, a robot tractor pull, atomic hockey, and robo-critters.
www.scmb.mb.ca/mrg.html

20-21 **RSA ROBOlympics**
Fort Mason, Herbst Paviliion, San Francisco, CA
Possibly the largest robot competition of 2004 and includes robot fighting, FIRA robot soccer, a bipedal race, BEAM, LEGO Mindstorms, nano sumo, and more. Over $10,000.00 in prize money is offered.
www.robolympics.net

28 **University of Florida Student Robotic Competition**
University of FL Conference Center, Gainesville, FL
This is the only robot contest you'll see where the robots are required to obey Asimov's three laws as part of the rules!
plaza.ufl.edu/niezreck/Robots_Competition_2004.html

April 2004

15-17 **FIRST Robotics Competition**
Georgia Dome, Altanta, GA
The national championship event for the FIRST student robot competitions. It's the largest FIRST event of the year and is open to the public.
www.usfirst.org

16 **Carnegie Mellon Mobot Races**
Wean Hall, CMU, Pittsburgh, PA
The 10th annual occurance of the now famous CMU Mobot race. Autonomous robots race to complete a complex course, passing through 18" finish gates along the way.
http://www.cs.cmu.edu/~mobot/

16-17 **OTEA National Robotics Competition**
Veterans Memorial Coliseum, Marion, OH
This contest is intended to replace the defunct RI/SME Robotics Challenge. Includes several autonomous robot events, as well as a radio-controlled event for beginners.
www.ohiotech.org/competitions.html

17 **RoboRodentia**
California Polytechnic State University, San Luis Obispo, CA
This is something like a micromouse event except that in addition to navigating the maze, the mice have to pick up balls and return them to a "nest."
http://ieee.ee.calpoly.edu/ieee_cs/

17 **UC Davis Picnic Day MicroMouse Contest**
University of California, Davis campus, CA
Every year, UC Davis has a campus-wide event known as Picnic Day. And every Picnic Day includes the annual MicroMouse contest. The event follows standard MicroMouse rules.
www.ece.ucdavis.edu/~ieee/umouse/umouse.html

18 **Trinity College Fire Fighting Home Robot Contest** — Trinity College, Hartford, CT
An autonomous robot must move through a mock house, locate a fire, and extinguish it. This year's contest will be the first without Jake Mendelssohn at the helm. He will be missed.
www.trincoll.edu/events/robot/

20-22 **DTU RoboCup**
Technical University of Denmark, Copenhagen, DENMARK
Imagine your typical line-following contest. Now add forks in the line, ramps, stairs, gaps in the line, shifts from indoor to outdoor lighting, reversals of the line shading (white to black), and 50 cm "gates" though which the robot must pass.
www.iau.dtu.dk/robocup/about_robocup.html

Beat Balance Metal Detector

by Thomas Scarborough

The circuit of Figure 1 may well represent an entirely new concept, being a hybrid between beat frequency operation (BFO) and induction balance (IB) metal detectors. Also, it arguably represents the simplest possible self contained metal detector.

Its performance, too, lies between BFO and IB. If it were a BFO design, its performance would be extremely good — if not unmatched. If it were an IB design, its performance would be mediocre. Even so, it has a few definite advantages over IB (see below).

To be specific, commerical BFO designs of the 60s and 70s rarely exceeded a 4" range for a 1" diameter coin (e.g., an old English penny), while modern bottom-of-the-range IB designs will pick up a 1" diameter coin at at least 5". In a best case, an IB design would pick up a 1" diameter coin at about 9".

By comparison, the Beat Balance Metal Detector will give a good signal at 5" for a 1" diameter coin.

The particular advantages of the design are its great simplicity and low cost, its easy set-up and adjustment, and some ability to auto-adjust to ground conditions through its two coils, which tend to balance each other out.

Not least, each coil has the opposite response to metal, so that it will potentially discriminate spatially. That is, it will indicate which coil is picking up metal — and this could have powerful applications in robotics.

BFO and IB in Concept

To understand the concept of the Beat Balance Metal Detector, it would help us to recap the principles which underlie it.

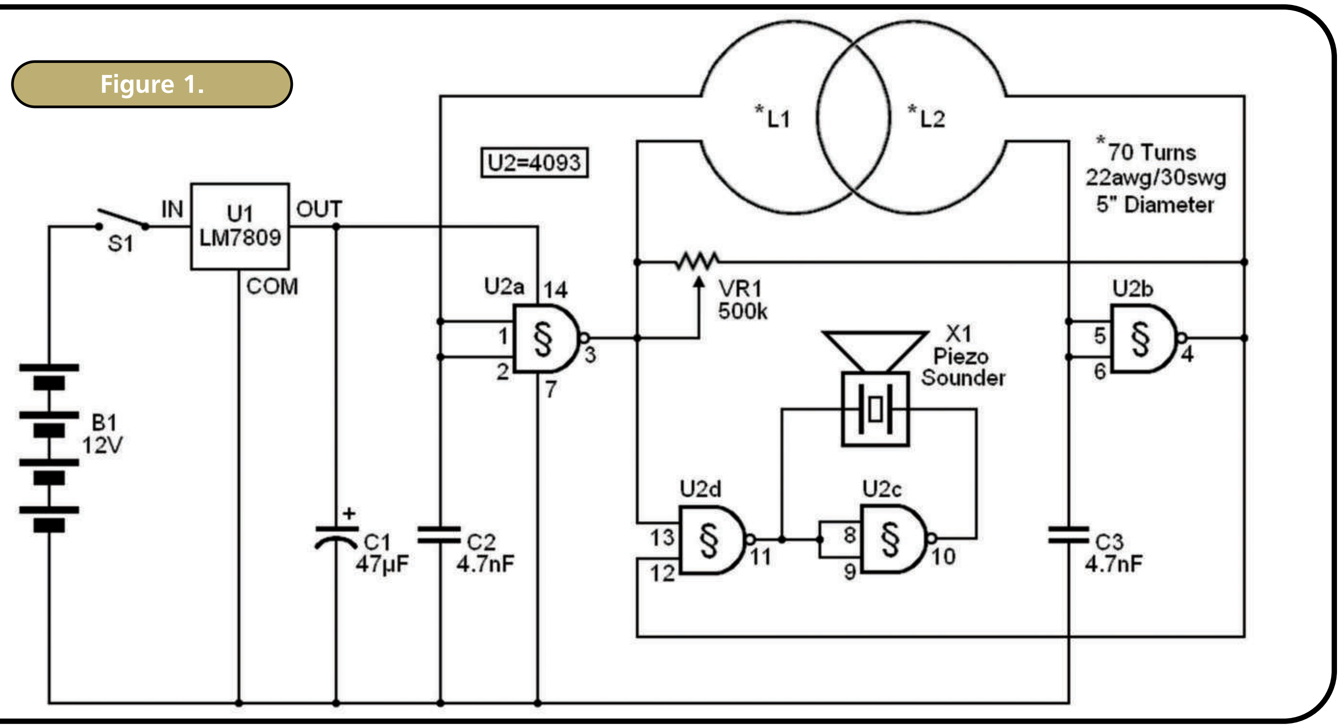
A BFO metal detector typically employs two high frequency oscillators which run side-by-side at almost the same frequency. One of these is called the reference oscillator, the other the search oscillator.

The search oscillator incorporates a pick-up coil, the inductance of which changes at the presence of metal — typically less than 1%. When this happens, the frequency of the search oscillator shifts, and its frequency in relation to the reference oscillator increases or decreases.

Now suppose that both the reference and the search oscillator oscillate at around 100 kHz. If these two frequencies are now mixed so as to produce an audible beat frequency (also called the difference frequency), the presence of metal might shift the beat frequency by several tens of Hertz — which is easily picked up by the ear.

Notice, therefore, that a small change in the frequency of the search oscillator (say 0.5%) is greatly magnified in the beat note, so as to cause a far larger shift in the audible beat

Figure 1.



frequency (perhaps 100%).

On the other hand, an IB metal detector employs two coils: a transmitter coil (Tx) and receiver coil (Rx). The Tx coil is driven by an oscillator with a frequency anywhere between audio and hundreds of kHz, thus setting up an alternating magnetic field around the coil.

The Rx coil is then positioned in such a way that it partly overlaps the Tx coil. By adjusting the amount of overlap, a point can be found where the voltages in the Rx coil "null," or cancel out, so that little or no electrical output is produced by the Rx coil. Thus, the coils are "balanced."

This balance is critical, and a metal object which enters the alternating magnetic field will distort the field, causing an imbalance, which results in a signal in the Rx coil. The signal is picked up by a level detector, which, needless to say, needs to be both as stable and sensitive as possible.

Generally speaking, IB metal detectors are about twice as sensitive as BFO. At the same time, their design and construction is far more critical, and cost will usually be significantly higher.

Hybrid Beat Balance

This leads us to what I have dubbed the "beat balance" principle (or BB for short — see the circuit

Figure 2a.

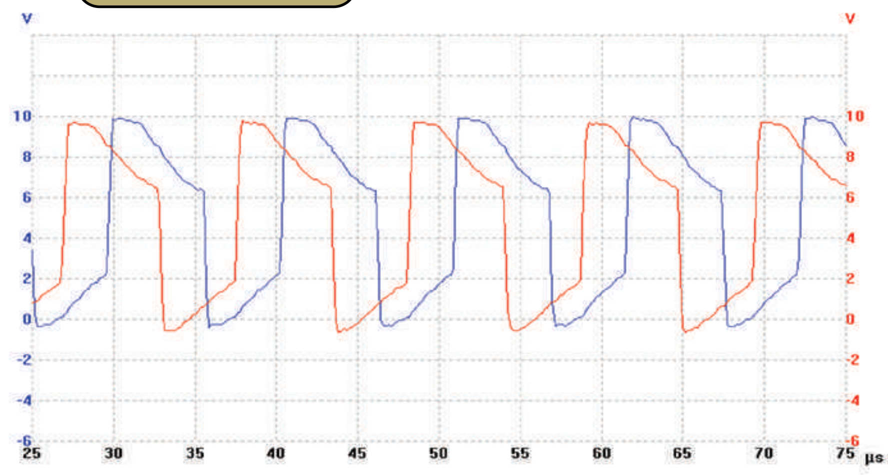
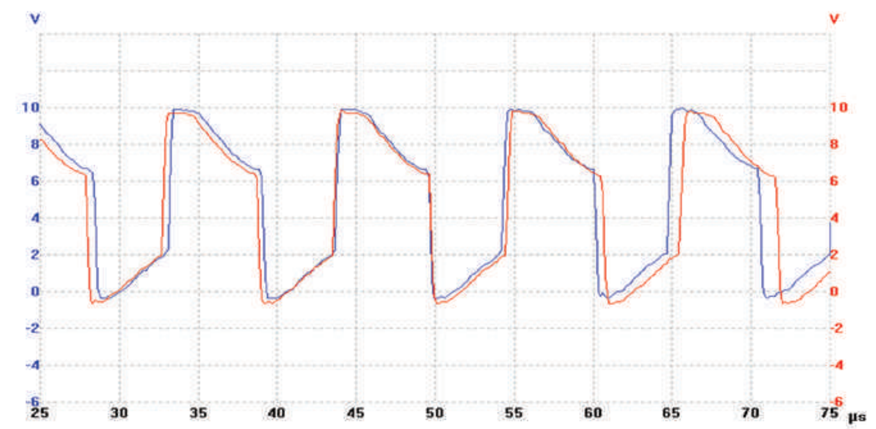


Figure 2b.



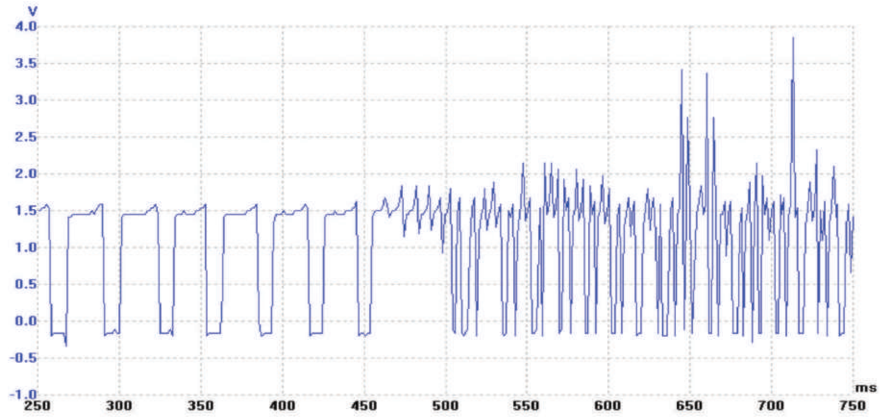


Figure 2c.

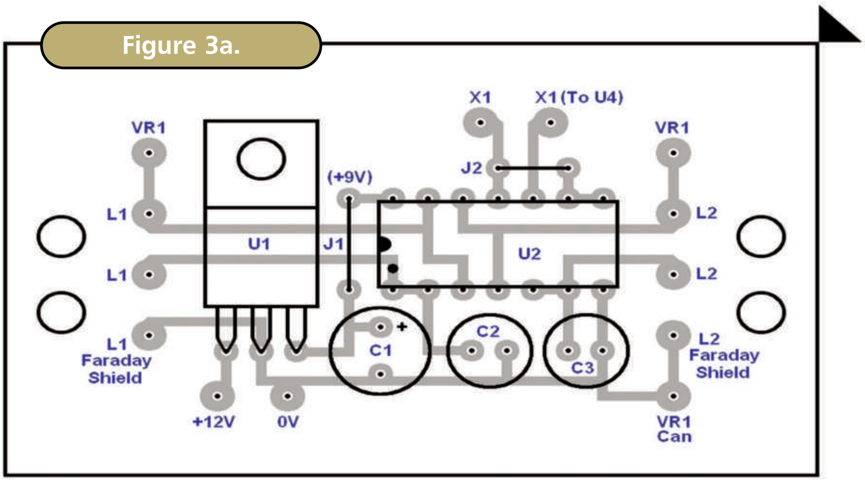


Figure 3a.

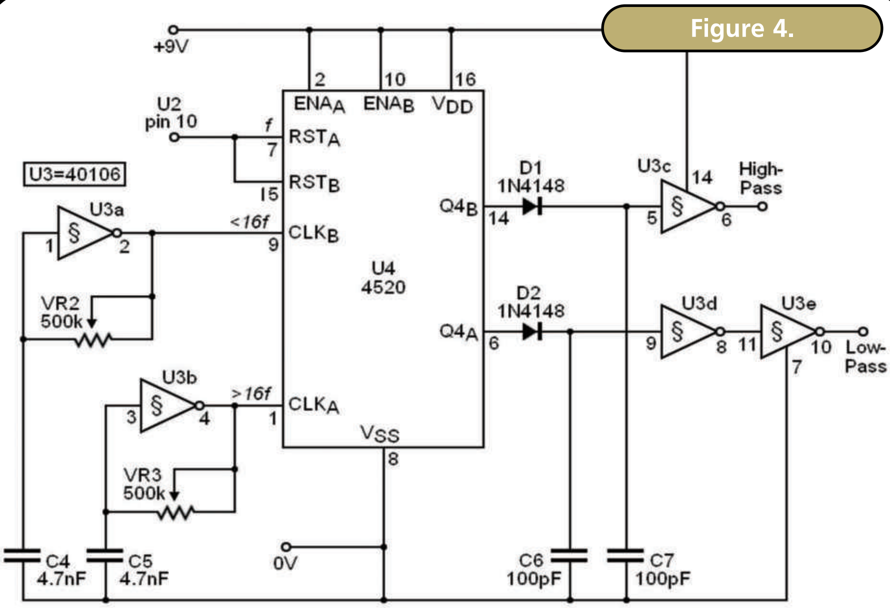


Figure 4.

diagram in Figure 1).

Instead of using a reference oscillator and a search oscillator as with BFO, the BB detector employs two search oscillators (U2a and U2b of Figure 1).

These represent two simplified CMOS-gate Colpitts oscillators (the capacitors at the output are omitted), whose frequency changes with variations in the inductance of the coils.

The frequencies of these two oscillators are mixed — similarly to BFO — and this is is accomplished through U2d. A difference frequency then appears at output pin 11.

Figure 2a shows the pulses at the outputs of U2a and U2b in the absence of metal, and Figure 2b shows when metal is detected.

Figure 2c shows the reaction of the mixer (U2c pin 11) when metal is detected. While we have the mixing of the two frequencies in mind, it is important to note that each of the two search coils (L1 and L2) gives an opposite response to metal. That is, one coil raises the frequency at the mixer's output, while the other lowers it.

This has a number of useful consequences. It reduces "ground effect," or the effect of mineralization of the ground on the detector's stability. Also — as has already been mentioned — it imbues the BB detector with spatial discrimination.

But what makes the BB detector different to BFO above all else, and significantly increases its range, is that mutual induction modifies the frequencies of both oscillators. This introduces the "balance" that is present in an IB metal detector, and boosts sensitivity some 50% beyond BFO.

The circuit adds a measure of control to this mutual induction by means of potentiometer VR1, which serves to tune the detector. This could be wired in series with a smaller value potentiometer (say 100K) for greater precision.

U1c is added as an inverter, so that piezo sounder X1 is operated in push-pull fashion, and this increases the volume. X1 may be substituted with a crystal earpiece, and this

would be particularly advantageous in noisy environments. U1 is used to optimize voltage stability (and thus frequency stability).

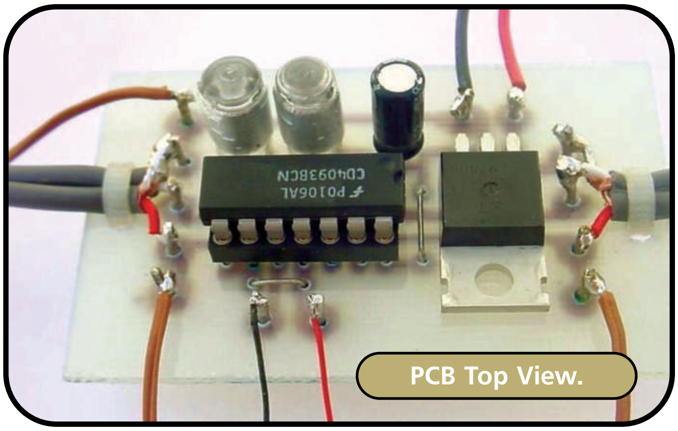
One more point deserves mention, and this is that the BB detector's coils (L1 and L2) may be separated — by almost any distance — and the detector will continue to function. In this case, it will lose its greater "BB mode" sensitivity, and will respond only as well as an ordinary BFO detector would do.

However, each coil will continue to give the opposite response, and if this is properly exploited, we again have the basis for spatial discrimination.

Robotics Applications

If we could detect when the Beat Balance Metal Detector's output has risen above a specific frequency, or has dropped below a specific frequency, we would be able to distinguish which of the two coils has detected metal.

This could have a number of applications. For example, if the BB detector were built into a robot, the robot could follow a strip of aluminum foil under a floor — alternatively, it could stay within an aluminum foil perimeter. Another possibility would be to avoid other (metal) robots — or to attack them!



PCB Top View.

Figure 4 offers a tested method to determine which of the two coils is picking up metal. This is provided simply as the basis for experimentation, and could be used equally well with many BFO, IB, and PI (pulse induction) designs. The best approach would be to wire up the circuit and experiment.

The output of the BB detector's mixer U2d (pin 11) is fed to the RSTA and RSTB pins of U4 (a 4520 CMOS dual binary counter — see Figure 4). Also, the 0 volt and +9 volt terminals of both circuits are connected.

The supply voltage of both circuits is not critical, and may be altered between about 5 and 15 volts, according to the need.

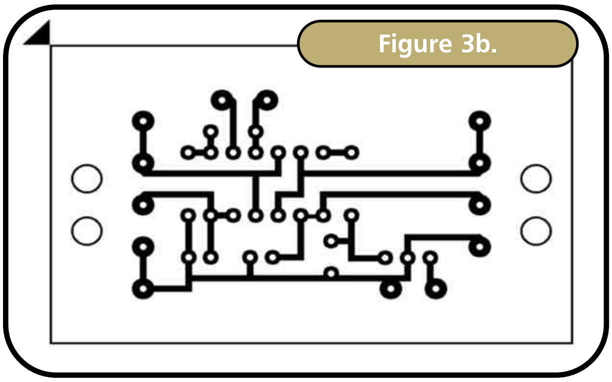


Figure 3b.


Search Head Coils.

The Beat Balance Metal Detector should be tuned to emit a steady tone, then the two filters should be tuned (through VR2 and VR3) to react individually to the presence or absence of metal.

Assuming that the frequency at the output of mixer U2d is f, then the high-pass filter's control frequency (based on a 40106 CMOS Schmitt inverter gate, U3a) should be >16f, and the low-pass filter's control frequency (U3b) should be <16f.

The high- and low-pass outputs in Figure 4 (U3 pins 6 and 10) are CMOS-logic compatible. For test purposes, these outputs may illuminate two LEDs by wiring a LED from each output to 0 V through a 1K series resistor. This gives an excellent indication as to how the filters are functioning.

Note that the Beat Balance Metal Detector's components (particularly regulator U1) could cause some drift as they warm up slightly at switch-on. One solution would be to mount U1 away from the circuit, or to employ a micropower regulator. The filters should be adjusted so as to accommodate any drift.

The BB detector and the filters should be set up together. That is, don't set up the BB detector on its own if the filters are going to be hooked up later — at least don't do any finalizing until everything has been set up as a whole.

A further advantage of the BB principle, which it shares in common with BFO, is that it is not too concerned about metal in its own vicinity (e.g., a metal shaft on the search head) — so long as it is adjusted to accommodate this in advance. Thus it could likely be mounted on a robot with a fair amount of metal in close proximity.

PARTS LIST

Resistors

VR1	500K linear potentiometer

Capacitors

C1	47 µF radial electrolytic, 16 volts
C2, C3	4.7 nF radial polyester

Semiconductors

U1	LM3809 9 volt regulator
U2	CMOS 4093 quad Schmitt NAND

Miscellaneous

S1	On-off switch
L1, L2	30 yards 22 AWG enamelled copper wire (each coil)
X1	Piezo sounder / element (no internal electronics)

Three yards quality screened stereo microphone wire, 2" x 1" copper-clad board, suitable ABS plastic enclosure (to fit batteries, PCB, and hardware mounting), base plate(s) for coils 9 1/2" x 6 1/2", knob with fixing nut for VR1, 14-pin DIP socket, two bare jump wires, solder pins, solder, etc.

Building the Circuit

The printed circuit board (PCB) measures about 1 1/2" x 2 1/2".

Begin by soldering jump wires J1 and J2, the 13 solder pins, and U2's 14-pin DIP socket.

Then solder the three capacitors (noting the correct orientation of electrolytic C1) and solder regulator U1 to the PCB.

Connect VR1 to the PCB by means of two suitable lengths of insulated wire, and take a third insulated wire from the PCB to VR1's metal can (this may also be taken to a washer on VR1).

Solder a battery clip to the PCB. Solder piezo sounder X1 to the PCB (or a 3.5 mm jack socket for a crystal earpiece).

Solder the two search coils to the PCB, using cable ties to secure the cables to the PCB — this will prevent the connections from coming loose under strain. Finally, insert U2 in the DIP socket on the PCB, noting its correct orientation. This is static sensitive, so discharge your body to earth ground before handling.

Switch S1, potentiometer VR1, and piezo sounder X1 (or a socket for a crystal earpiece) are mounted on the case. Select a case which is large enough to accommodate the circuit, hardware mounting, and a 12V battery pack.

Winding and Setting the Coils

I used 70 turns of 22 AWG (0.315 mm) enamelled copper wire wound on a 120 mm diameter former for each coil. Faraday electrostatic shields may be added to the coils if desired, and these are connected to 0 volts on the PCB. These serve to reduce ground effect and capacitive coupling.

The winding of the coils is not critical, and a little give and take is permissible. The coil former may be made of a sheet of stiff cardboard with 12 pins stuck through it at suitable angles (the heads facing slightly outwards).

Each coil is then wound around the pins, and temporarily held together with stubs of insulating tape passed under the coil and pressed together over the top. The coils may be jumble-wound.

Once a coil has been wound, the pins are removed, and it is tightly bound by winding insulating tape

around its entire circumference. In this design, it is not important which of the coil's wires are which, except of course that the Faraday shields should in both cases be connected to the cable's screen and to 0 volts on the PCB. Scrape the enamel off the ends of the coil's enamelled copper wires to solder them.

To add a Faraday shield, use some long, thin strips of aluminum foil. Twist a 100 mm length of bare wire around the coil, over the insulating tape. This wire provides electrical contact for the Faraday shield, and is soldered to the connecting cable's screen.

Beginning at the base of the bare wire, the foil is wound around the circumference of the coil, so that no insulating tape is still visible under the foil — but the foil should not complete a full 360 degrees. Leave a small gap — say 10 mm — so that the foil does not meet after having gone all of the way around.

Do this with both coils. Each coil is now again tightly bound with insulating tape around its entire circumference. Attach each of the coils to quality twin-core (stereo) screened microphone cable.

The two coils need to be set very rigidly in position on the search head. Their position in relation to one another is critical, and there should be no movement of the coils when the detector is in use.

I usually set twinned coils in clear polyester resin, which is available from most hardware stores, together with the necessary hardener or catalyst. Use a stiff, non-metallic plate for the search head (I used masonite in the prototype). Begin by placing both coils on the plate, on top of one another, and set VR1 to its mid-position.

Switch the metal detector on, then move the coils slowly apart. When the coils have all but been separated from one another, a tone will be heard in piezo sounder X1.

Adjust the coil's position so that this is a low tone. Then drill holes and use cable ties to fasten the coils in this position on the plate. Bend the coils afterwards for any further adjustment.

If polyester resin is used, note that this is extremely runny, and sticks faster than many glues. Make sure you first plug any holes in the search head plate, also giving it a suitable border to contain the resin before pouring. You might keep a segment of the coils free, to allow for final adjustment through bending the coil.

Set-up and Use

When all is complete, switch on and allow several seconds for the circuit to settle. Adjust VR1 until a low tone is heard in the piezo sounder or crystal earpiece. Ideally, VR1 should be adjusted to its mid-position at this point. The coils may be bent slightly on their plate to achieve this.

Bring a metal item close to the coils. It will be found that one coil causes the tone in the piezo sounder to rise, while the other causes it to fall.

A 1" diameter coin should cause the tone to shift sufficiently for this to be discerned without trouble at 5", and large metal objects will be discerned at 20".

Note that the Beat Balance Metal Detector offers some discrimination — that is, it may be possible to determine whether the metal found is ferrous (e.g., bottle tops) or non-ferrous (a pot of gold?).

In use, hold the search head close to the ground for searching, sweeping it slowly to and fro. Keep in mind which coil causes which response (a rise or a fall in frequency), so that you may know under which coil the treasure lies.

The thought of finding treasure is not as far-fetched as it may seem, particularly if one chooses one's areas for searching intelligently. My son and I found an old wreck, and appeared on national TV. More recently, I discovered metal under a rock stopper at an ancient site — however, this has yet to be excavated. **SV**

The Love Of All Things Robotic

by Steve "Mouse" Silverstein

Years before I became a Disney Imagineer, I was already deeply interested in robots and controlling things electronically and by computer. As a teenager, my after-school hours were often spent experimenting and building my own Animatronic figures and programming control systems — sometimes well into the next morning. The notion of using invisible bits and electrons at my command to cause a mechanical device — a real and tangible thing — to move or perform some physical action still fascinates me to this day. So when the editor of *SERVO Magazine* asked me to help contribute, I enthusiastically jumped at the chance. I am hard pressed to think of a better way to help stimulate the imaginations of fellow robot enthusiasts than through the articles contained in this magazine, and I wish the publisher the best of luck in building a loyal following of readers.

If you're anything like me (I think there's a good chance you are because you're reading this magazine!), you are naturally drawn to the challenge of using your technical prowess to creatively solve problems. What's more, you aren't content in having only a passing understanding of technical things. You want to master them. You aren't satisfied unless you can make your own discoveries, often by trial and error. You feel compelled to use your imagination to think of fun ways to explore and understand the world around you.

Having robotics as a hobby or a profession is a wonderful means to that end. And besides, robots are just plain cool! Whether your interests make you partial to combat robots, entertainment animatronics, Space Station robot arms, manufacturing robots, A.I. or whatever — to be able to make a machine that can remotely (or autonomously) become an extension of yourself in just about any way you can imagine is pretty amazing stuff!

When I first became interested in robotics as a hobby, there were practically no books or magazines available on the subject. There was no Internet available to use as a research tool, and you were lucky if you could find a network of other people who were also robot enthusiasts. On the one hand, I'm thankful that I had to do a lot of the research and studying on my own — the hard way. On the other hand, there were many times that I really appreciated having a mentor available to help get through those tough spots (you know, those seemingly impossible problems that lead to frustration and thoughts about giving up).

If you are just starting out experimenting with robots, the wealth of information on the subject available to you today is absolutely mind-boggling. Still, knowing what to look for and where to find it can be a major challenge. Stick with it, though, and if you happen to hit a technical snag, look for help online or in-person. There is a high probability you can connect with someone willing to help you find that elusive tidbit of information you're searching for.

And, if you are a robotics veteran, I encourage you to become a mentor to someone who is just getting his or her feet wet. Being a knowledgeable guide who helps someone along the path of discovery is a wonderful way to share your common enthusiasm of, and interest in, all things robotic. **SV**